Naval Research Laboratory

Washington, DC 20375-5320

NRL/MR/6180--99-8411

U.S. Navy Halon 1211 Replacement Plan Part II — Halon 1211 Requirements Review

D.P. Verdonik
S.T. Laramee
P.J. DiNenno

Hughes Associates, Inc.
Baltimore, MD

F.W. Williams

Navy Technology Center for Safety and Survivability
Chemistry Division

November 1, 1999

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1, 1999	Interim Report — 1998

4. TITLE AND SUBTITLE

U.S. Navy Halon 1211 Replacement Plan Part II — Halon 1211 Requirements Review

5. FUNDING NUMBERS

6. AUTHOR(S)

D.P. Verdonik,* S.T. Laramee,* P.J. DiNenno,* and F.W. Williams

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
Washington, DC 20375-5320

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/PU/6180--99-8411

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Air Systems Command
Patuxent River, MD 20670

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

*Hughes Associates, Inc.
Baltimore, MD

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A review and analysis was performed on the development of the currently fielded Halon 1211 systems and the more recent development of the Halon 1211 alternative systems to determine the historical fire threats and firefighting requirements. The review revealed that specific Halon 1211 system capabilities have not historically been based on well defined fire threats. In order to develop the specific firefighting requirements for the Halon 1211 replacement systems, fire incident data for Calender Years 1977-1991 and Fiscal Years 1993-1995 were reviewed and analyzed in terms of the types of fires encountered in the field, severity of the fires, the frequency of occurrence of each type, and the effectiveness of Halon 1211 systems on these fires. Based on these results, the firefighting requirements and system requirements were developed for shore based and shipboard Crash, Fire and Rescue operations.

14. SUBJECT TERMS

Halon 1211
Halon alternatives
Crash, fire and rescue (CFR)
Aviation firefighting
Firefighting agents

15. NUMBER OF PAGES

91

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

CONTENTS

U.S. NAVY HALON 1211 REPLACEMENT PLAN
PART II - HALON 1211 REQUIREMENTS REVIEW

1.0 INTRODUCTION

1.1 Background

The U.S. Navy currently uses five firefighting agents for suppressing fires on flight lines and flight decks: water, Aqueous Film Forming Foam (AFFF), Halon 1211, potassium bicarbonate (PKP) and carbon dioxide (CO_2) [NATOPS, 1994]. While each of these agents is potentially effective for flammable liquids or other combustibles typically encountered on flight lines and flight decks, each has advantages or disadvantages for a particular application. AFFF and water are the primary agents while PKP, Halon 1211 and CO_2 are secondary agents used with the primary agent or alone. The secondary agent is used alone in those situations where the primary agent is not effective and cannot completely extinguish the fire. It is often used in combination with the primary agent when increased effectiveness is required. For example, while AFFF is very effective in fighting pool fires and providing cooling, it is limited in fighting three-dimensional and deep seated, hidden fires. The three secondary agents are better than AFFF in fighting three-dimensional fires and hidden fires, but do not provide effective cooling or burnback protection.

An important distinction between the five agents is the potential for causing collateral damage or damage caused by the agent to hot metal surfaces, elecronics or avionics. Halon 1211 is recognized as the agent that will cause the least collateral damage. While Halon 1211 and CO_2 may, in some extreme circumstances, both be considered 'clean,' CO_2 may cause collateral damage due to thermal shock or static discharge. PKP and AFFF are not clean agents and may cause considerable collateral damage. For this reason Halon 1211 has become the agent of choice

Manuscript approved October 4, 1999.

in many aviation firefighting applications. The ability to reduce or eliminate collateral damage has been thought to be particularly important for engine fires and internal electrical fires. The aircraft may be placed back into service more quickly and at a lower cost when solely Halon 1211 is used to extinguish the fire [Leonard et al., 1992].

Halon 1211 was not the first clean, halocarbon agent to be used for aviation firefighting. Chlorobromomethane (CB), also known as Halon 1011, was used by the U.S. Air Force (USAF) as a streaming agent as early as the 1970s for flight line firefighting. Halon 1011 demonstrated the ability to limit collateral damage; however, it had corrosion and toxicity properties that were less than ideal. In the late 1970s, the USAF sponsored testing of Halon 1211 as a replacement for Halon 1011 [Chambers, 1977]. Halon 1211 was shown to possess the same positive attribute in limiting collateral damage but was much less toxic and corrosive than Halon 1011. The USAF sponsored work and the experience with Halon 1211 in Europe led to the recommendation to replace Halon 1011 in flight line extinguishers [Novotny et al., 1975]. Although no definitive literature source has been found that delineates how the 150 pound capacity was determined, there is a fair amount of anecdotal information available [Chambers, 1977; Burns, 1996; Huston, 1996; Darwin 1996-1997].

1.2 Halon 1211 on Navy (Ground Based) Flight Line Applications

The Navy began to incorporate Halon 1211 into flight line firefighting as early as 1977 when Twin Agent Units (TAUs) with AFFF and Halon 1211 were purchased to replace TAUs with PKP [Rout, 1997; NAVFAC, 1996]. Soon after, Halon 1211, 150 pound, wheeled flight line extinguishers were purchased by the Navy and Air Force. The 150 pound units are intended to provide an initial attack of fires by maintenance and operations crews. Halon 1211 was also placed within Crash Fire Rescue (CFR) vehicles such as the P-19. The decision to require 500 pounds of Halon 1211 on CFR vehicles appears to be based on what would fit in available space rather than determining a precise quantity required to meet a particular fire threat. Within military CFR vehicles, 500 pounds was found to fit in the space previously used by PKP [Darwin, 1996-1997].

In 1982, the FAA performed tests to qualify Halon 1211 as an acceptable alternative to PKP as a secondary agent for flight line CFR operations. These tests proved that Halon 1211 performed adequately and was subsequently approved for use. The FAA also came across the same 500 pound requirement by a different route. It appears that the 500 pound criterion was derived from an analysis of how much agent could be carried by a standard ¾ ton pickup truck [Wright, 1995]. Although not derived from an evaluation of agent required to meet a particular fire threat, the 500 pound value has become the de-facto standard.

The National Fire Protection Association (NFPA) published the "Standard for Aircraft Rescue and Firefighting Services at Airports" in 1988 [NFPA 403, 1988]. Minimum extinguishing agent quantities and discharge rates were provided for the primary and secondary agents based on the airport category. Halon 1211 and PKP were given a one to one parity with respect to both agent quantities and discharge rates. There does not appear to have been any specific tests performed or referenced in the NFPA committee decision [Darwin, 1996-1997]. The latest, 1993, version of NFPA 403 provides the same requirements for PKP and Halon 1211 as the 1988 version [NFPA 403, 1993].

1.3 Halon 1211 on Flight Decks

Halon 1211 found its way to the flight deck of U.S. Naval vessels in the mid-1980s as a result of the crash of an EA-6B aircraft on the USS NIMITZ [Carhart et al., 1987]. AFFF, PKP and Halon 1211 were evaluated against a standard debris pile fire developed by the Naval Research Laboratory (NRL) to simulate the fire threat encountered on the USS NIMITZ, a pool fire with aircraft debris and running fuel (leak) fires. Based on the work performed by NRL, Halon 1211 was chosen as the secondary agent to AFFF for flight deck firefighting. The flight deck firefighting vehicle, the P-16, was retrofitted to provide 400 pounds of Halon 1211 in addition to the on-board AFFF. As with the flight line CFR vehicles, the decision to require 400 pounds of Halon 1211 appears to be based on the space available within the P-16 vehicle [Darwin, 1996-1997].

1.4 Environmental Issues

During the same time period that the Navy was increasing its reliance on Halon 1211, the international environmental community was linking the use of chlorofluorocarbons (CFCs) and halons to the destruction of the stratospheric ozone layer. The first international agreement was the Vienna Convention for the Protection of the Ozone Layer, signed in 1985. The Vienna Convention requires signatories to take appropriate measures to comply with its provisions including all protocols in force to protect against human activities that modify the stratospheric ozone layer. The major protocol under the Vienna Convention is the Montreal Protocol on Substances that Deplete the Ozone Layer, signed in 1987. At present, there are 156 Parties to the Protocol. The Protocol has been amended twice, the first Amendments to the Protocol were enacted in 1990 during a meeting in London and are, hence, termed the London Amendments. In 1992, the Copenhagen Amendments were adopted. Under the Copenhagen Amendments, production of Halon 1211 ceased in the US (and the rest of the developed nations) on 1 January 1994.

In the US, the Protocol was ratified by the Senate in 1988. The status of the Protocol as an International Treaty means that it takes precedence over national law. For example, Title VI of the Clean Air Act Amendments of 1990 (CAAA) requires that the more stringent control measures listed within the CAAA or the Protocol must be followed; the Environmental Protection Agency (EPA) has the responsibility to administer the regulations to adjust the control measures to ensure, as a minimum, compliance with the Protocol.

1.5 Halon 1211 Use and Availability

As a consequence of the Montreal Protocol, the Navy and all other users of Halon 1211 must rely on, and share, the quantities of Halon 1211 currently in existence. Recent actions under the Montreal Protocol have been aimed at determining the quantities of halons required to meet fire protection needs versus the quantities available. Surpluses of Halon 1211 may be targeted for mandatory collection and destruction. These actions may serve to reduce further the long-term availability of Halon 1211.

Since 1993, the Department of Defense (DOD) has established a strategic reserve of Halon 1211 to supply the needs of the services in lieu of relying on production. The quantities of Halon 1211 purchased, in supply, and used were not tracked in the logistics system. Local purchases at dozens of locations hampered efforts to get precise data. Best estimates were developed to determine the quantities of Halon 1211 required for the Reserve [DDLA, undated (circa 1994)]. The major source of Halon 1211 to support the field has been the Reserve since 1993. With this main source of Halon 1211, the ability of the logistics community to track Halon 1211 issued to the field has been significantly increased. In addition, other military activities, government agencies and industry have been performing research, development, test and evaluation (RDT&E) to develop and prove-out technologies to replace Halon 1211. Recent changes within the Montreal Protocol, technology developments and availability of additional Halon 1211 logistics data provide both the need and opportunity to re-evaluate the continued use of Halon 1211.

A project directed at evaluating the continued reliance on Halon 1211 for aviation firefighting was developed. The work covered in the entire effort will be performed and reported in four parts: (1) Halon 1211 Alternative Development Status, (2) Halon 1211 Requirements Review, (3) Halon 1211 Mission Critical Reserve Evaluation and (4) Halon 1211 Replacement Program Plan. The work covered in this report is for Part II – Halon 1211 Requirements Review.

2.0 OBJECTIVE

The overall objective of this project is to provide the basis for a detailed Halon 1211 Replacement Program Plan. The purpose of the program plan is to ensure that the Navy is adequately prepared to support aviation CFR operations on flight lines and flight decks through continued use of Halon 1211 and/or replacement technologies.

To meet the overall objective, the plan will be based on (1) an evaluation of the development and status of Halon 1211 replacement technologies; (2) an assessment and delineation of fire protection operational requirements that currently use Halon 1211; (3) quantification of the amount of Halon 1211 within the Navy, including the reserve, available to meet the requirements; (4) an estimation of the Halon 1211 needed to meet the fire protection requirements and (5) assessment of policy and procedural changes that may be implemented to reduce the required Halon 1211. The work presented in this report covers item (2): an assessment and delineation of fire protection operational requirements that currently use Halon 1211.

The objective for the work performed under Part II was to develop specific Navy firefighting requirements for use in evaluating potential Halon 1211 alternative agents/systems. The stated USAF requirements and FAA requirements will be evaluated against the developed Navy requirements to determine if they will be suitable to meet the Navy needs.

3.0 APPROACH

3.1 Drop-in Agent Approach

Two different approaches may be used to perform the re-evaluation of continued Halon 1211 use in developing the Replacement Plan. The first approach starts with the premise that every application that currently uses Halon 1211 must continue to use a Halon 1211 like replacement with exact attributes and capabilities of Halon 1211. This is the so called 'drop-in'

philosophy where the one new agent must work in all current Halon 1211 equipment without modification. The new drop-in agent would have all of the positive attributes of Halon 1211, but would not have the negative environmental impacts. It essentially defines the requirement as Halon 1211. It defines the purpose as replacing Halon 1211 and sets all of the performance objectives at those equal to Halon 1211. This approach limits the ability to create significant advances in technologies. The lure of the drop-in approach is that if it is successful there will be limited logistical and cost impacts. The major disadvantage is that if it is unsuccessful Halon 1211 will be the only agent available to meet the firefighting need. It has not been successful to date, following 12 years of research and development [Carpenter, 1997]. A Naval Studies Board enpanelled to evaluate Halon 1301 (CF_3Br) replacements found that "It is unlikely that a drop-in replacement agent will be discovered that will exhibit all of the beneficial properties of halon 1301 and not also exihibit a significant environmental impact"[National Academy of Sciences, 1997].

3.2 Systems Engineering Approach

The second approach starts with the premise that each application that currently uses Halon 1211 can be defined by a series of firefighting and related requirements. Instead of assuming that the requirement is to replace Halon 1211, it places the need at performing the required firefighting. It requires understanding and defining the firefighting requirements for each application. This philosophy places the emphasis on the systems engineering required to meet the threat and not solely on the agent itself. Tests need to be developed that adequately measure the ability of the system to meet the documented requirement. It requires a better understanding of the operational and technical requirements. The major advantage is that a wider range of technologies can be explored. This approach will also lead to a better understanding of the science and engineering involved, and enhances the ability to develop significant advances in technology.

Several organizations have shown great success with the systems engineering approach in resolving Halon 1301 applications. The Navy has proved out inert gas generators in the V-22 and F/A-18E/F, and the Army has proved out HFC-227 (FM-200™) in the RAH-66 for engine nacelle fire protection. CO_2 portables, water mist and dry chemicals are all replacing Halon 1301 in

various applications. HFC-236 has been commercialized as a 1211 replacement while CO_2 and dry chemicals are being used extensively in the private sector as Halon 1211 "replacements." All of these successful alternatives would have been eliminated from consideration using the drop-in approach. To date, no drop-in agent has been implemented in any fire protection application. Emphasis has been placed on the systems engineering approach in performing and reporting this work.

3.3 Assignment II – Halon 1211 Requirements Review

Fire incident data from the Naval Safety Center were collected and analyzed to determine the types and frequencies of fire events. Two separate sets of data were reviewed: (1) Navy incidents covering the years 1977-1991 and USAF fire incidents covering the years 1981-1991, from a previous study [Leonard et. al, 1992]; and (2) Navy, USMC, USAF and Army fire incidents covering Fiscal Years (FY) 1993-1995 for incidents reporting Halon 1211 use.

A review of the NATOPS was performed to (1) identify the fielded equipment that use Halon 1211 for aviation firefighting, (2) determine the intended use of the equipment, e.g., types of fires (engine and electrical) and types of fuels (Class, A, Class B, Class C, and/or Class D) and (3) if possible, determine specific fire fighting/protection requirements used to develop fielded equipment. Additional information was collected through telephone conversations and meetings with users, designers and developers of the current equipment.

The specific items addressed are given below [Leach, 1996a].

- Develop separate inventories of shipboard and shore-based hardware;
- Define hardware requirements for each application:
    - Research the historical need being met by the current systems,
    - Review the NATOPS for equipment and needs,
    - Assess the "as good as Halon" replacement objective and
    - Compare and contrast Navy and Air Force requirements;

- Research historical fire incidents:
  - Develop fire suppression effectivity analysis and
  - Identify incidents better suited with alternative protection.

4.0 US NAVY AND USMC FIREFIGHTING EQUIPMENT

The 15 March 1994 version of the NATOPS Navy Aircraft Firefighting and Rescue Manual provides descriptions of the firefighting equipment currently employed by the Navy and Marine Corps (USMC) [NATOPS, 1994]. Two separate types of equipment exist: (1) mobile firefighting and rescue vehicles and (2) portable extinguishers including the wheeled flight line units.

4.1 Mobile Firefighting and Rescue Vehicles

Chapter 4, Aircraft Firefighting and Rescue Vehicles and Associated Equipment, lists the firefighting and rescue vehicles used by the Navy and USMC: seven types of vehicles for shore-side and two vehicle systems for shipboard firefighting [NATOPS, 1994]. The primary firefighting agent is AFFF for all vehicles/systems. Some of the systems also contain internal supplies of Halon 1211 for use as a clean and/or secondary agent. For one class of systems, PKP is also supplied as the secondary agent to AFFF. Of the eight vehicle systems listed in the NATOPS, five contain Halon 1211: (1) three shore-based CFR vehicles, (a) Amertek CF 4000L (7160), (b) Oshkosh T-3000 (7190) and (c) Oshkosh P-19/P-19A (7160); (2) P-16/A Firefighting vehicle for flight deck use; and (3) Twin Agent Units (TAUs) used both shore-side and shipboard. The descriptions of these vehicles in the NATOPS generally indicate which agents are contained within the vehicles. However, the NATOPS did not indicate that Halon 1211 was contained within the T-3000. Information obtained through discussions with the Navy east coast Fire Marshal confirmed that Halon 1211 was installed on the vehicle [Rout, 1997]. Several different models of TAUs exist and only some contain Halon 1211. The other TAUs contain PKP. The results are provided in Table 1 with the quantities of Halon 1211 installed on each vehicle/system.

Table 1. Vehicle/System Halon 1211 Quantities

Vehicle/System	Quantity of Installed Halon 1211
Shore Based CFR Vehicles	
Amertek CF 4000L	500 lb
Oshkosh T-3000	500 lb
Oshkosh P-19/19A	500 lb
Shore Based TAUs	200 lb
P-16 (Shipboard)	400 lb
Shipboard TAUs	350 lb

An inventory of all Navy shore side CFR (excluding USMC) vehicles was supplied by Naval Facilities Engineering Command (NAVFAC) [NAVFAC, 1996]. The inventory included the organization (by Unified Identification Code), the make, model and year of the equipment. A second inventory was provided by the east coast Fire Marshall for the CFR equipment for east coast activities that listed additional information [Rout, 1996]. In addition to the same information contained in the overall NAVFAC inventory, the Fire Marshal inventory included status, replacement year, and original purchase price.

An area of concern was the status of Halon 1211 in TAUs. The NATOPS listed three different TAUs in service which may contain Halon 1211 or PKP. The east coast Fire Marshal indicated that TAUs purchased between 1977 and approximately 1986 contained Halon 1211 [Rout, 1997]. TAUs purchased after 1986 do not. However, some of the 1977-1986 TAUs may have been retrofit away from using Halon 1211. Another area of concern is that the inventory tracks the vehicle that was used for the TAU and not the TAU itself. In some cases, the TAU is no longer in use, but the vehicle is. These issues will lead to a small uncertainty.

Attempts to receive consolidated information from the USMC similar to that provided by NAVFAC were unsuccessful. It was determined that the only CFR vehicle that contains Halon 1211 is the P-19. A centralized listing of the total number P-19s ‘owned’ by the USMC was obtained. To obtain the remainder of the data, separate telephone calls were made to the USMC

Aviation Fire Protection and Recovery Officers [MCAS, 1997]. The resulting Navy inventory and the USMC P-19 roll-up are provided in Appendix A.

An inventory for the P-16 and TAU-2H used ship board was not identified. In order to develop an inventory the list of the current fleet, by class of ship was obtained through the Navy home page on the world wide web [USN, 1997]. To determine the number of firefighting vehicles/systems on each class of ship, the Support Equipment Recommendation Data (SERD), dated 12/02/96, were obtained for the P-16 and the TAU-2(H) [SERD:P-16, 1996; SERD:TAU-2H, 1996], and the NATOPS was reviewed for vehicle/system requirements. The SERD lists the Basis of Issue for each class of ship and represents the number that each class is authorized to carry. The analysis to develop the inventory is discussed below. The resulting inventory is provided in Appendix A.

NATOPS Chapter 7, Aviation Ship (CV/CVN) Crash, Fire and Rescue Organization and Operations, provides the requirements for Halon 1211 in mobile equipment and portable extinguishers for aircraft carriers. Three P-16s and three TAUs are required to support flight operations [NATOPS, 1994]. The Support Equipment Recommendation Data (SERD) for the P-16 and for the TAU-2H list these same quantities as the total authorization for each ship [SERD:P-16, 1996; SERD:TAU-2H, 1996]. At least one TAU or P-16 is required on the hangar deck. Apparently, it is typical for the TAU-2Hs to be maintained on the hanger decks to meet this requirement [Darwin, 1996-1997]. At the 1996 NATOPS Conference, a change was approved for the next version of NATOPS to change the requirement to a total of three Mobile Firefighting Vehicles (MFFVs) to support flight operations [NATOPS, 1996]. This change appears to keep the requirement for three P-16s (or the new P-25) but eliminates the requirement for TAU-2Hs for the flight deck. It is not clear how this change will affect the authorization of the TAU-2Hs.

NATOPS Chapter 8, Amphibious Aviation Ships (LPH/LHA/LHD) Crash, Fire and Rescue Organization and Operations, provides the Halon 1211 requirements for these three classes of ships [NATOPS, 1994]. Two P-16s and three TAUs are required except for LPHs where one P-16 and two TAUs are required. There is a discrepancy between the NATOPS and the SERD. The SERD indicates that all three ship classes are authorized two P-16s and two

TAU-2Hs [SERD:P-16, 1996; SERD:TAU-2H, 1996]. At the 1996 NATOPS Conference, a change was approved for the next version of NATOPS to change the requirement to three MFFVs instead of the two P-16s and three TAUs [NATOPS, 1996]. This change appears to increase the requirement for P-16s (or the new P-25) and eliminates the requirement for TAUs for the flight deck. A second change was approved that indicates that a TAU-2H may be mounted an MD-3A tow tractor for use on the flight line. This change would allow meeting the increase in required MFFVs without increasing the number of P-16s/P-25s.

NATOPS Chapter 9, LPD and Other Air Capable Ships Crash, Fire and Rescue Organization and Operations set the Halon 1211 requirements for these ships [NATOPS, 1994]. Only the LPD has a requirement for an MFFV. However, the SERD for the P-16 does not authorize any for the LPDs. At the 1996 NATOPS Conference, a change was approved for the next version of NATOPS to indicate that a TAU-2H may be mounted an MD-3A tow tractor for use on the flight line, presumably to meet the requirements of the MFFV. It must also be noted, however, that the SERD for the TAU-2H does not indicate an authorization for the LPDs. It appears that the LPDs historically used TAUs containing PKP [Walsh, 1996-1997]. The PKP TAUs are being replaced by attrition with TAUs using Halon 1211. It is not clear if these are TAU-2Hs or a different model because the SERD does not indicate an authorization.

The inventory for ship board systems was developed under the assumptions that (1) the SERDs are the definitive source for systems on board ship and (2) each ship currently carries exactly what is authorized on the SERDs. Changes in the NATOPS for system requirements were not used in developing the inventory. While NATOPS changes may affect the SERDs in the future, they do not reflect the current systems in place. Based on the SERDs, four classes of ships are authorized Halon 1211 vehicles/systems: (1) CV/CVN, (2) LPH, (3) LHA and (4) LHD [SERD:P-16, 1996; SERD:TAU-2H, 1996]. Twelve CV/CVNs are in the Fleet, each authorized three P-16s and three TAU-2Hs. Two additional CVNs are being built. Two LPHs, five LHAs and five LHDs are currently fielded, each authorized two P-16S and two TAU-2Hs. One additional LHD is being built. In addition, NAWC Lakehurst reported that the LPDs are or soon will be authorized to carry Halon 1211 TAUs [Walsh, 1996-1997]. Eleven fielded LPDs and one being built will need the TAUs.

4.2 Portable Extinguishers

The NATOPS lists three different agents for hand held and wheeled fire extinguishers: Halon 1211, CO_2, and PKP [NATOPS, 1994]. No centralized inventory of portable hand held or flight line extinguishers was found within the Navy, USMC, or the USAF. For flight line units, the Item Manager located at Robins AFB was contacted to determine if quantities and locations were tracked. Since 1984, the Item Manager has not purchased any units [Williams, 1997]. However, it is possible, and likely, that local purchases occurred after that time. No definitive data on quantities or locations of flight line extinguishers are provided by the Navy to the Item Manager.

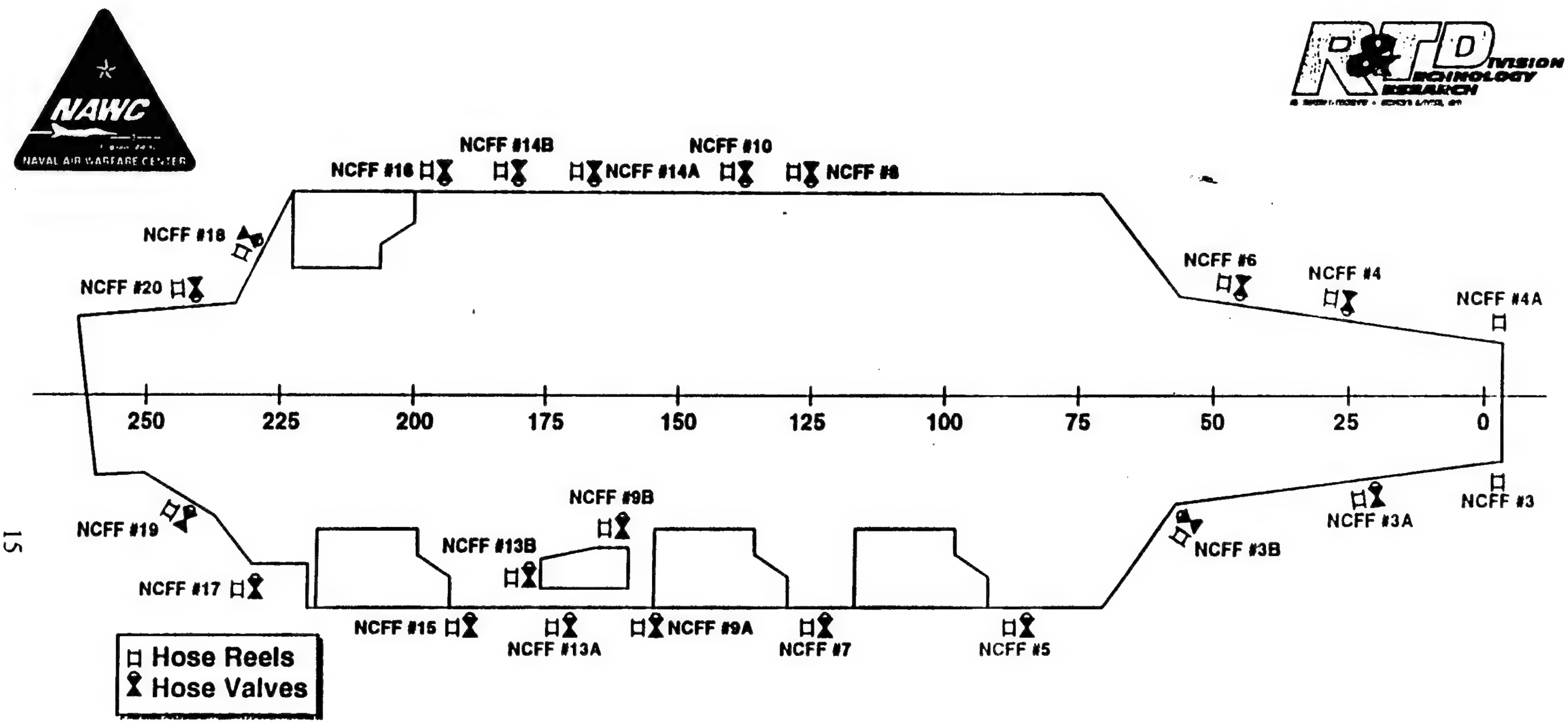
In order to try to develop an inventory, the requirements for hand held and flight line extinguishers in the NATOPS were reviewed. NATOPS Chapter 4, Aircraft Firefighting and Rescue Vehicles and Associated Equipment, Section 4.2.2 Emergency Rescue Equipment, provides a list of required items on all major firefighting equipment [NATOPS, 1994]. The major firefighting vehicles are defined as the M-1000, P-4A, P-15, P-19, CF4000L and the T-3000. Each of these vehicles, and others as needed, are required to carry a 20 pound Halon 1211, 18 or 27 pound PKP and two 15 pound CO_2 extinguishers.

NATOPS Chapter 3, Firefighting Agents and Equipment, Section 3.3, Airfield Fire Protection Requirements, states the requirements for flight line extinguishers [NATOPS, 1994]. The primary flight line extinguisher is the 150 pound, wheeled Halon 1211 unit. PKP wheeled units are also acceptable. The quantities of extinguishers required is provided in the NATOPS based on the number and size of aircraft supported at the airfield. A summary of the requirements for the flight line parking area is provided below. All references to Halon 1211 extinguishers are for the flight line unit.

- Small and Medium Aircraft — one Halon 1211 extinguisher per 3 aircraft
- Large Aircraft — one Halon 1211 extinguisher per 2 aircraft
- C-5 Aircraft — two Halon 1211 extinguishers per aircraft
- Hot Refueling Points — one Halon 1211 extinguisher per two points/stations

- Concurrent Fueling and Service
    - Without Passengers — one Halon 1211 extinguisher (In addition, one major crash vehicle capable of responding in 3 minutes)
    - With Passengers — one Halon 1211 extinguisher (In addition, one major Aircraft Reserve Fire Fighting vehicle (ARFF) positioned at the aircraft with turrets manned and pumps ready)
- High Power & New Engine Runs — Two Halon 1211 extinguishers (In addition, one major ARFF capable of responding in 3 minutes)
- Combat Aircraft Ordnance Loading — one Halon 1211 extinguisher per 2 aircraft

NATOPS Chapter 7, Aviation Ship (CV/CVN) Crash, Fire and Rescue Organization and Operations, provides the requirements for Halon 1211 in mobile equipment and portable extinguishers for aircraft carriers. Two requirements exist for portable extinguishers. Each AFFF hose outlet on the flight deck will contain one Halon 1211 or one CO_2 and one PKP extinguisher [NATOPS, 1994]. Figure 1, prepared by Naval Air Warfare Center (NAWC), China Lake, provides an outline of the locations of the 22 AFFF Hose Stations for USS Dwight D. Eisenhower, CVN 69 [NAWC, 1997]. The USS Dwight D. Eisenhower contains the CO_2 and PKP extinguishers and not the Halon 1211. Although there is an option provided in the NATOPS, the use of CO_2 and PKP is the most likely for all of the aircraft carriers [Darwin,



- 22 AFFF Hose Stations
- Each Station
  - 1 - 18 lb. PKP (60 BC) min
  - 1 - 15 lb. CO_2 (10 BC) min
- Total BC Rating
  - PKP 22 X 60 = 1320 BC min
  - CO_2 22 X 10 = 220 BC min

    1540 BC min
- Same BC Rating as 6 + 150 lb. Halon 1211
  - 6 X 240 = 1440 BC
- Equivalent BC Rating to approximately 1000 lbs. of Halon 1211

Fig. 1 – Location of hose reels and hose valves on the flight deck of the USS Dwight D. Eisenhower (CVN69) [NAWC, 1997]

1996-1997]. These ships were fielded with the CO_2 and PKP, and it is unlikely that the ship has retrofit these units to Halon 1211. No wholesale change out has been sponsored by the Navy. Each ship would have to purchase the Halon 1211 units at their own expense.

In addition to the extinguishers at the AFFF hose stations, it is required that the crash and rescue tools on CV/CVNs include four Halon 1211, CO_2 or PKP and three fresh water portable extinguishers [NATOPS, 1994]. As with the extinguishers at the AFFF hose stations, the use of CO_2 and PKP are the most likely. At the 1996 NATOPS Conference, a change was approved for the next version of NATOPS to add the requirement that 7 foot extensions connected to the nozzle be provided for CO_2 extinguishers [NATOPS, 1996]. No requirement was found in the NATOPS for portable extinguishers on the hangar deck of aircraft carriers.

NATOPS Chapter 8, Amphibious Aviation Ships (LPH/LHA/LHD) Crash, Fire and Rescue Organization and Operations provides the Halon 1211 requirements for these three classes of ships [NATOPS, 1994]. The requirements for portable extinguishers on the flight deck are somewhat different than for the aircraft carriers. Similar to the aircraft carriers, one Halon 1211 or one CO_2 and one PKP extinguisher shall be mounted at each AFFF hose station on the flight deck. Unlike for the aircraft carriers, the specific size of the extinguisher is set: 20 pound Halon 1211, 15 pound CO_2 and 18 pound PKP. In addition, seven Halon 1211 or CO_2 extinguishers on the LPH flight deck and nine Halon 1211 or CO_2 extinguishers on the LHA flight deck shall also be permanently fitted with 5 foot, insulated extension pipes at the nozzle. Portable extinguishers are also required on the hangar deck. Each AFFF hose station is required to have one Halon 1211, CO_2 or PKP extinguisher mounted nearby. Four portable extinguishers are also required in the crash locker. Either Halon 1211, PKP or CO_2 extinguishers are acceptable. Although no sizes are specified, it is assumed that they are the same size as those required on the flight deck.

NATOPS Chapter 9, LPD and Other Air Capable Ships Crash, Fire and Rescue Organization and Operations set the Halon 1211 requirements for these ships [NATOPS, 1994]. The AFFF hose stations are required to have one Halon 1211 or one CO_2 and one PKP extinguisher [NATOPS, 1994]. No sizes for the extinguishers are provided. There is a note that helicopter operations require two additional 15 pound CO_2 extinguishers with 5 foot extensions. Portable extinguishers are not required in the tool roll.

An analysis of the number of flight line extinguishers expected at a shore side based on the NATOPS was attempted. The actual quantities of flight line extinguishers were obtained for several bases [Verdonik et al., 1997]. In all cases, the number of flight line extinguishers present greatly exceeded the minimum number required by the NATOPS. On average, two to three times as many extinguishers were present, but in one case, nearly ten times the number required were present. Based on this finding and the allowance for different types of extinguishers on board ship, no further attempts were made to develop an inventory for flight line or hand held extinguishers because the data were not available.

5.0 AGENTS, DOCTRINE, AND TACTICS

The NATOPS indicates that the use of Halon 1211 units, both hand held and wheeled (150 pound flight line), are intended primarily for Class B and Class C fires, but may be used successfully on Class A fires as well. Three cautionary notes are included for Halon 1211: (1) Halon 1211 is not to be used on Class D fires because of the potential for explosion, (2) the discharge of Halon 1211 may create a health hazard due to the neat agent and the pyrolysis products and (3) inhalation of Halon 1211 may be fatal. CO_2 in 15 pound handheld and 50 pound wheeled extinguishers are also intended primarily for Class B and Class C fires. Two cautionary notes are included in the NATOPS: (1) exposures to high concentrations for a prolonged period can be fatal and (2) the use of CO_2 to inert atmospheres is prohibited due to the potential for sparking upon discharge. PKP extinguishers are intended for Class B fires only. Two cautionary notes are included in the NATOPS: (1) avoid exposing dry chemicals to moisture when servicing

the extinguishers because they will harden and (2) when PKP is directed at or ingested by an aircraft engine or accessory section, the maintenance officer must be notified.

NATOPS Chapter 6, Firefighting and Rescue Operations, prescribes a priority order for use of the three agents based on the fire scenario [NATOPS, 1994]. A synopsis of the NATOPS follows.

1. General Engine Compartment Fires.

Halon 1211 and CO_2 are the primary agents. If the fire cannot be extinguished with Halon 1211 or CO_2, AFFF is to be used. However, as in the case for PKP, the use of AFFF must be reported to the maintenance officer.

2. Internal Engine Fires.

Halon 1211 and CO_2 are the primary agents. A cautionary note indicates that CO_2 and Halon 1211 may cause thermal shock when discharged directly into the engine. No information is provided about the potential use or effects of other agents.

3. Electrical and Electronic Equipment.

Halon 1211 and CO_2 are the primary agents for Class C fires. A special note indicates that CO_2 should not be used to "inert" the space because of the potential for sparking to occur. No information is provided about the potential use or effects of other agents.

4. Tailpipe Fires.

Windmilling of the engine should be tried first to blow out the fire. If that is unsuccessful, then the primary agents are Halon 1211 and CO_2. The agents should be directed into the exhaust duct. If unsuccessful, the agent should then be directed into the intake duct. No information is provided about the potential use or effects of other agents.

5. Hot Brakes.

a. Grease and bearing lubricant fires:

Primary agents are Halon 1211 and water fog. No information is provided about the potential use or effects of other agents.

b. Rubber tires:

Primary agents are Halon 1211 and water fog No information is provided about the potential use or effects of other agents.

c. Hydraulic fluids:

The primary agent is water fog. A cautionary note indicates that Halon 1211 may initially extinguish the hydraulic fluid, fire but reflash is a concern do to the lack of cooling from the agent. No information is provided about the potential use or effects of other agents.

6. Composite Material re-enforced with carbon/graphite or boron/tungsten fibers.
No information is provided on agents for extinguishment. It is required that firefighting and rescue personnel wear respiratory protection during the response. No indication is given that flight line or crew personnel should attempt to extinguish the fire with portable equipment.

7. Internal Firefighting on Large Frame Aircraft
No direct information is provided for primary firefighting agents. However, the procedures indicate that the agent should be bounced off of the fuselage ceiling to create a sprinkler effect, suggesting that water is considered the primary agent. In the section for developing appropriate response procedures, it is suggested that the quantity of Halon required to reach 6% for various compartments should be prepared. It is assumed that this refers to Halon 1211, but the recommended concentration would be greater than the Lowest Observed Adverse Effect Level (LOAEL).

NATOPS Chapters 7, 8 and 9 also prescribe the specific requirements and positioning of the MFFVs and TAUs for shipboard operations. The requirements are similar for all classes of ships, but some specific details are different for the aircraft carriers. A synopsis of the requirements by class of ship is provided below.

Launch

For CV/CVNs with two MFFVs operational, one is positioned with a view of FLY 2, and one is positioned with view of FLY 3 and waist catapults. For LPHs/LHAs/LHDs/LPDs, one MFFV is positioned with the best view of the launch area. The MFFVs shall be positioned, manned and running from "start engines" until launch.

Recovery

For CV/CVNs with two MFFVs operational, one is positioned with a downwind approach to the landing area and one is positioned in the FLY 1 area. For LPHs/LHAs/LHDs/LPDs, the MFFV is positioned to provide an unobstructed approach to as many landing spots as possible. The MFFVs shall be positioned, manned, and running until recovery is completed.

Respot

For CV/CVNs, one MFFV shall patrol the entire flight deck during all respots, rearming, and/or refueling. For LPHs/LHAs/LHDs/LPDs, the MFFV is positioned to respond anywhere on the flight deck.

Hangar Deck

For CV/CVNs, a minimum of one TAU/MFFV should be available during flight quarters. For LPHs/LHAs/LHDs, a minimum of one TAU should be available and centrally located during flight quarters.

Fueling

For CV/CVNs, the roving MFFV shall be considered to fulfill the requirements for portable extinguishers during JP-5 refueling on the flight deck. (No further information was found in the NATOPS that described this requirement). For LPHs/LHAs/LHDs/ LPDs, the manned, positioned MFFV shall be considered to fulfill the requirements for portable extinguishers during JP-5 refueling on the flight deck.

Limited Flight Operations/Single Launch and Recovery

For all ships, one manned MFFV should be located in the immediate vicinity where the flight operations will occur.

Maintenance Turnups Flight Deck

For all ships, one manned MFFV should be centrally located to the aircraft.

Maintenance Turnups Hangar Deck

For CV/CVNs, one TAU or MFFV should be positioned in the immediate vicinity, or if not available, one AFFF hose line manned in the vicinity.

Ordnance Handling

For CV/CVNs, one manned TAU or MFFV is required, and for LPHs/LHAs/LHDs/ LPDs, one manned MFFV should be located in the vicinity for each concentrated weapons loading/off loading evolution.

Minimum Initial Response

For all classes of ships, the minimum initial response includes MFFV(s)/TAU(s) and two portables (Halon 1211, CO_2, or PKP). For mass conflagration, a constant resupply of portable extinguishers is required.

Shipboard Tactics

Aircraft Debris Pile/Running Fuel Fires

For all ships, the tactic is to attack first with AFFF hose teams to diminish the high levels of radiant heat. When radiant heat of the fire is lowered, attack with Halon 1211 from the P-16 using a minimum of 5-second bursts until the fire is out.

Wet Starts

Essentially the same for all ships as discussed previously in general tactics with the exception that the use of AFFF must also be reported to the maintenance officer. Halon 1211 and CO_2 are the primary agents. If the fire cannot be extinguished with Halon 1211 or CO_2, AFFF is to be used. There is a discrepancy for the LPDs where CO_2, AFFF and PKP are given parity when Halon 1211 is not available.

Helicopters

For LPDs, there are special considerations for helicopters. A fire watch should be posted on startups. Halon 1211 or CO_2 extinguishers with 5-foot extensions should be immediately available.

6.0 ANALYSIS OF NATOPS

6.1 Agent Requirements

The preceding section on agents, doctrine and tactics in the NATOPS provide limited insight into determining the firefighting requirements. The fact that AFFF is the primary agent is an indication that the predominant threat is considered to be two-dimensional Class B fires. For secondary agents, the predominant requirements are for three-dimensional Class B and Class C fires. All three agents, Halon 1211, CO_2 and PKP are effective for both of these threats. The listing for Halon 1211 also indicates that it can be used successfully on Class A fires, but the NATOPS does not make a strong case for Class A requirements.

The priority order for use of the agents in a given scenario appears to be directly based on collateral damage potential. PKP is thought to cause the most collateral damage for engines and electrical components. As such it is placed last, behind Halon 1211, CO_2 and AFFF in the priority order. The approved agents and tactics are based on a requirement for a clean agent, i.e., Halon 1211 or CO_2.

6.2 System Requirements

The firefighting requirements based on system performance is less clear than for the agents. A lack of consistency exists in the NATOPS with respect to system capabilities. In some shipboard applications, both PKP and CO_2 extinguishers together are considered equivalent to a Halon 1211 extinguisher. The CO_2 would meet the requirements for a clean agent with three-dimensional Class B and Class C capability, but its two-dimensional Class B capability is quite limited. A 15 pound CO_2 unit is rated 10BC. The 18 pound PKP unit is rated 60-80 BC. The fact that the PKP extinguisher is required with the CO_2 extinguisher suggests that an increased Class B capability is a requirement. A 20 pound Halon 1211 extinguisher is rated 4A80BC supporting the need for the additional Class B capability. In other cases, however, either Halon 1211, CO_2 or PKP extinguishers are acceptable. This suggests two items for shipboard portable extinguishers (1) if only PKP is acceptable, then there is no clean agent requirement and (2) if

only a CO_2 extinguisher is acceptable, then the two-dimensional Class B requirement, for a secondary agent is small, i.e., the 10B rating for the fifteen pound CO_2 units.

The inconsistency in apparent requirements is also present for shore side portables. All six major shore side firefighting vehicles are required to carry a 20 pound Halon 1211, 18 or 27 pound PKP , and a 15 pound CO_2 extinguisher. All three extinguisher types are required. These extinguishers are intended to be used in cases where the fire is small enough that the internal water, AFFF, and Halon 1211 would be in excess of needs. It is not clear why all three extinguisher types are required for flight line use when all three are not required for shipboard use. The lack of consistency suggests that specific firefighting requirements for portable extinguisher have not been used to develop required system capabilities.

The same difficulty in resolving consistent firefighting requirements exists for vehicles as well. Three of the six major firefighting vehicles for shore side use contain 500 pounds of Halon 1211. For shipboard use, the P-16 contains 400 pounds of Halon 1211 and 365 gallons of premixed AFFF and the TAU-2H contains 350 pounds of Halon 1211 and 80 gallons of premixed AFFF. For the LPDs, some of the TAUs still contain 200 pounds of PKP. In several cases, the TAU or P-16 may be used to meet the NATOPS requirement. In other cases, the TAU and P-16 may be replaced by an AFFF hose line. This suggest that the quantities of agents and specific capabilities required in the NATOPS have not been developed based on specific firefighting requirements.

Another important example is that no portable extinguishers are required on the P-16. In many cases, these vehicles are fitted with portable extinguishers by the crew. It is more common for these extinguishers to be PKP or CO_2 than Halon 1211. The lack of a definitive requirements carries over to the new P-25. The current version of the P-25 does not contain internal supplies of Halon 1211. The only clean agent and only secondary agent capabilities are three 20 pound Halon 1211 portables strapped to the vehicle. This suggests that the clean agent and secondary agent requirements are relatively small. However, the P-16 was retrofit from PKP to Halon 1211 in response to the USS NIMITZ fire [Carhart et al., 1987]. The need for a secondary agent was demonstrated and used in the retrofit decision. While it is possible that many small fires may be

adequately handled with the three portable Halon 1211 (clean agent) extinguishers augmented with the CO_2 or Halon 1211 extinguishers at the AFFF stations, it is not clear that the mass conflagration will be adequately handled with the small quantity and flow rate of the secondary agent.

While it is difficult to derive a definitive set of firefighting requirements from the NATOPS, it does provide a good basis for the generic requirements. For agents, the NATOPS clearly defines Class B/C requirements and does not appear to place a high degree of need on Class A capabilities. In actuality, however, the 'fuel' in a Class C fire is a Class A material (e.g., wire insulation and circuit board). From an extinguishment perspective, it does not matter if the wire insulation caught on fire due to an electrical problem or due to contact with a jet fuel fire. The requirement is to extinguish Class A materials with an agent with limited or zero electrical conductivity.

Based the current doctrine and tactics in the NATOPS, there is 'requirement' for a clean, multipurpose (Class A/B/C) agent for portable and wheeled extinguishers. These extinguishers are needed (1) as a first line of attack, (2) as the clean agent, (3) as a secondary agent to AFFF for increased capability and (4) for those cases where the internal supplies of the secondary agent (Halon 1211 or PKP) are in excess of needs of a particular fire. The requirement for streaming and throw capabilities is also evident by the required 5-foot/7-foot extensions for CO_2. It is not clear if the current 20 pound Halon 1211 extinguishers meet the throw requirement.

The generic requirements for vehicles are less certain. There is a need for a secondary agent with at least three-dimensional Class B and Class C capability. For shore side vehicles, the need for "large" internal supplies of a clean agent is not demonstrated within the NATOPS. The exact fire size rating or other basis for agent quantities in existing system could not be derived from the NATOPS.

7.0 HISTORICAL DEVELOPMENT

7.1 Historical Development of 150 Pound Extinguishers

To elucidate further the basis for the capabilities, quantities of agents and types of systems, a literature review was performed to determine the requirements that were used to develop the systems. No definitive literature source was identified that delineates how the 150 pound capacity for the wheeled flight line extinguishers was determined. From information in the literature and anecdotal information, it was possible to piece together an explanation. The precursors to the 150 pound Halon 1211 extinguisher were the 125 pound PKP unit and the 10 gallon and 20 gallon Halon 1011 units [Chambers, 1977; Burns, 1996; Houston, 1996a, Darwin, 1996-1997; Novotny et al., 1975]. The advantage of Halon 1011 versus PKP was that it was considered a clean agent. The disadvantages of Halon 1011 were that it was corrosive, irritating, and toxic [Chambers, 1977].

Due to the severe disadvantages of Halon 1011, the USAF tested Halon 1211 as a suitable clean agent alternative in 1975-1976 [Chambers, 1977]. Their work included scenarios for (1) thin pool and deep pool fires, (2) engine fires, (3) tire fires and (4) obstructed and three-dimensional fires. Extinguisher hardware configurations, pressures and discharge rate were evaluated for the different fire types. Based on the results for an optimized system, it was recommended that serviceable 10 gallon Halon 1011 flight line extinguishers be retrofit with approximately 125 pounds of Halon 1211. To replace non-serviceable units, it was recommended that Halon 1211 units with a capacity of 150 pounds be purchased as the standard unit. No information was given in the report why the higher capacity was recommended for new units.

The decisions that 125 and 150 pounds of Halon 1211 in optimized systems were acceptable were based on the series of tests run by the USAF [Chambers, 1977]. Their work showed that 125 pounds of Halon 1211 in the 10 gallon Halon 1011 unit allowed for proper optimization of the system. At 125 pounds of Halon 1211, the determined optimum fill density of 50 to 55 percent was obtained. When combined with other optimized parameters, e.g., pressures and nozzles, the Halon 1211 extinguisher performed adequately compared to the Halon 1011

extinguisher for the specific tests scenarios. However, as with other test series discussed under Part I of this effort, the evaluation used existing extinguishers as the baseline [Carpenter, 1997]. No evidence was found that the tests were designed to simulate specific requirements based on verified field needs. The tests are generic to the types of fires expected to be encountered in the field, e.g., engine and wheel, but the specific parameters are not necessarily representative of actual fire conditions. For example, the pre-burn times were established to ensure that adequate fuel remained during the test and not to provide heating of surfaces for re-ignition [Chambers, 1977]. Hot wheel/brake fires develop because the build up of heat in the wheel/brake assembly ignites wheel grease and hydraulic fluid, which in turn may ignite a tire. Hot surface re-ignition of wheel/brake fires is an important aspect in evaluating the effectiveness of extinguishment. The USAF test series does not appear to have evaluated this effect. The 125 pound Halon 1211 unit may have performed adequately compared to the 10 gallon Halon 1011 unit, but there was no indication that a true set of requirements was developed to evaluate either the Halon 1011 or the 125 pound Halon 1211 units.

While no specific information was identified on how the exact size of the 10 gallon Halon 1011 was developed, the approximate size, and hence capability, may have been developed qualitatively. Within the same USAF work, it was recommended that the 20 gallon Halon 1011 units not be retrofit to Halon 1211 [Chambers, 1977]. This decision was based on the expected users for these large units. Flight line units are used for first aid attack by maintenance staff and crew. Because they are not extensively trained and do not have protective clothing, it was not believed reasonable to expect that they would try to fight very large fires. The 20 gallon Halon 1011 units were typically placed near fuel storage facilities to provide increased firefighting capabilities. The higher capabilities of the 20 gallon Halon 1011 unit was not deemed to be an operational requirement for crew and maintenance staff use on flight lines. This qualitative analysis is the only indication that the original Halon 1011 extinguishers may have been 'sized' based on an expected fire threat. Unfortunately, no further information is contained within the report, and no further information was found in the literature.

No indication was found in the literature that the decision to choose exactly 150 pounds of Halon 1211 was based directly on a developed operational requirement. Instead, it appears to

have been a side result of changing from Halon 1011 to Halon 1211. The stainless steel tanks required by the corrosive Halon 1011 could be replaced by less expensive mild steel tanks [Huston, 1996]. If an off-the-shelf mild steel tank could be used for the new Halon 1211 units, it would help to reduce the development and procurement costs. The existing container for the 125 pound PKP unit appears to have been chosen for three reasons: (1) it was available off-the-shelf, (2) it was made of less expensive mild steel and (3) it held 150 pounds at the optimum 55 percent fill density (slightly more than the 125 pounds of Halon that was determined to be equivalent to the 10 gallon Halon 1011 unit). The quantity of 150 pounds of Halon 1211 was not based on a hard operational requirement or required capability and does not necessarily represent a capability that must be duplicated.

7.2 Historical Development of Quantities on Mobile Firefighting Vehicles

As with the 150 pound extinguishers, no definitive literature was found that identified the development of the quantities of Halon 1211 on military CFR vehicles. Anecdotal information indicates that the decision to install 400 pounds of Halon 1211 on the P-16/A firefighting vehicles and 350 pounds of Halon 1211 on the Twin Agent Units (TAUs) used onboard ships was based on the quantity that would fit in the space previously used by PKP [Darwin, 1996-1997]. The same space analysis was also performed for land based military CFR vehicles, (i.e., Oshkosh P-19 and T-3000, and Amertek CF 4000L). The space previously used by PKP would accommodate 500 pounds of Halon 1211. For commercial, land-based CFR vehicles, the FAA also came across the same 500 pound requirement but by a different route. The FAA reported that the 500 pounds was derived from an analysis of how much agent could be carried by a standard ¾ ton pickup truck [Wright, 1995]. A ¾ ton pick-up can carry 1500 pounds. Subtracting the weight for the personnel, tank, and delivery system left approximately 500 pounds for Halon 1211 or dry chemical. The FAA also reported that the only operational requirement was that approximately 100 pounds of Halon 1211 is needed to extinguish a typical flight line fire, but no further information was provided. The decision to carry 500 pounds on military and commercial CFR vehicles, 400 pounds on the P-16, and 350 pounds on TAUs was not based directly on a specific fire fighting requirement. The capabilities represented by these quantities do not necessarily represent requirements that must be duplicated.

7.3 Historical Development of Quantities in Hand Held Extinguishers

As was the case for the flight line extinguishers, no direct information on Halon 1211 quantities in hand held extinguishers was found in the literature. The performance capabilities of commercial extinguishers are provided through a rating system based on extinguishing preplanned fires of a determined size as described in UL 711 [NFPA 10, 1994]. Class A ratings (ordinary combustibles) are based on wood and excelsior. Class B ratings (flammable liquids) are based on 2 in. deep n-heptane square pan fires. A Class C rating (electrical/energized systems) requires that the agent be non-conductive to electricity and is not based on any fire tests. While the UL ratings are generally considered to describe system capabilities, it must be noted that there is no direct translation between the UL ratings and actual performance of the extinguishers for the types of fires encountered in CFR operations. Therefore, it is possible to have extinguishers with acceptable military flight line performance and no UL rating and vice versa.

Personal communications with manufacturers of Halon 1211 alternative agents/extinguishers indicated that the work to size and qualify the new extinguishers was based on obtaining a Class A rating [Moore, 1996; Nadolny, 1996]. For example, two different size extinguishers are commercially available from the same company with different Class A ratings but the same Class B rating. This is also generally the case for the Halon 1211 extinguishers. It is more typical for each size of a Halon 1211 extinguisher to have a different Class A rating than to have a different Class B rating [Underwriters Laboratories, 1995]. To meet many building codes, a UL Class A rating is required. The use of hand held extinguishers in buildings is a much greater market than for CFR operations. The Halon 1211 extinguishers were developed and optimized to obtain 1A through 4A ratings. The Class B capabilities for each Halon 1211 extinguisher are provided but do not appear to have driven the quantities, flow rate, or throw characteristics of the system. Therefore, the extent to which a specific UL rating for either Class A or Class B effectiveness is a hard requirement for CFR operations is debatable.

8.0 FAA

8.1 FAA Firefighting Requirements and Capabilities

Draft FAA Advisory Circular 150/5210-XX, "Aircraft Fire Extinguishing Agents," has been prepared by the FAA [FAA, undated]. When approved, the draft is to replace the current Advisory Circular 150/5210-6C, "Aircraft Fire and Rescue Facilities and Extinguishing Agents," dated January 28, 1995 [FAA150/5210-6C, 1995]. The new Advisory Circular will provide the recommended level of fire protection for FAA covered facilities conversion factors for use in determining equivalency between types of agents, additional information on liquid and dry agents and the required performance for evaluating new agents..

The FAA considers foams as the primary agent for aircraft CFR. The draft Advisory Circular still recognizes the use of protein foam, fluoroprotein foam, AFFF, and Film Forming Fluoroprotein (FFFP) foam as acceptable foam agents [FAA, undated]. It lists the equivalency between protein foams and AFFF as 1 gallon of water for AFFF is equivalent to 1.5 gallons of water for protein foams. This equivalency is based on the application rate at which the initial intensity of the fire 'in the practical area' is reduced by 90% in one minute. The established application rate meeting this requirement for protein foams versus AFFF is 0.2 and 0.13 US gpm/ft^2 respectively.

Other equivalencies provided in the draft Advisory Circular are provided below [FAA, undated].

- 1 gallon of water for protein foam — 8 pounds of dry chemical powder (except below)
- 1 gallon of water for protein foam — 7 pounds of potassium based dry chemical powder
- 1 gallon of water for protein foam — 16 pounds of CO_2
- 1 pound of dry chemicals — 2 pounds of CO_2
- 1 gallon of Halon 1211 — 16 pounds of dry chemical powder
- 1 gallon of Halotron I — 12 pounds of dry chemical powder

Of special interest are the equivalency for gallons of Halon 1211 and pounds of dry chemical powder versus gallons of Halotron I and pounds of dry chemical powder. NFPA 403

provides the equivalency of 1 to 1 on a pound basis between Halon 1211 and dry chemicals [NFPA 403, 1993]. No information was found in the literature that identified the origin of the equivalencies between dry chemicals and Halon 1211. A participant in the NFPA committee discussions on equivalency reported that the decision was based solely on the general consensus of the committee and that no testing was performed to document these values [Darwin, 1996 - 1997].

Although the NFPA and FAA both provide a pound for pound equivalency for Halon 1211 versus PKP, there is a difference in UL ratings for similarly sized extinguishers. The 125 pound PKP unit is rated as high as 320BC. The 150 pound Halon 1211 unit is rated as high as 30A240BC [Underwriters Laboratories, 1995]. (The term 'as high as' is used above in recognition that the UL 711 tests do not rate the agent alone but rate the performance of the overall system. It is possible for the same quantity of agent in a different extinguishing system to obtain a lower rating than those given above. UL 711 prescribes the standard tests for rating of an extinguisher against Class A crib fires, Class B pool fires, and acceptability in Class C fires.) There are two differences between the PKP and Halon 1211 units: Class A capability and the size of the Class B pool fire extinguished.

The position of the FAA Technical Center, Airport Technology R&D Branch for establishing acceptable clean agent alternatives is that the test protocols should be as close as possible to the original tests series used to qualify Halon 1211 [Wright, 1995]. Section 3.b.(4) of the draft Advisory Circular provides the methodology for determining alternatives to Halon 1211 [FAA, undated]. It states "the average of three tests for each of the protocols shall be compared to a baseline extinguishment for Halon 1211 to determine the equivalency of the product" and recognizes that the tests must be performed by an independent testing laboratory. The test protocols required are listed in FAA Report DOT/FAA/AR 95/87 [Wright, 1995]. Four fire tests are required: three-dimensional, inclined plane; simulated engine nacelle running fuel fire; 800 ft^2 dry pool fire extinguishment; and simulated wheel well. In addition agent throw-range tests are required. For the most part, these tests measure the effectiveness against Class B fuels in varying scenarios. There may be a limited Class A capability measured in the simulated wheel well fire. However, it is likely that the test more adequately measures a different Class B threat, i.e.,

hydraulic fluid versus JP-4 than a Class A threat. Additional information on these tests in reported under Part I – Development of Halon 1211 Alternatives of this work [Carpenter et al., 1997].

The draft Advisory Circular also lists the required tests for determining equivalency of new dry chemicals [FAA, undated]. The baseline established is for PKP and sets application rates between 5 and 7 pounds/second [Wright, 1995]. The test protocols for dry chemical agents are provided in FAA-RD-78-105 [Geyer et al., 1978].

The extent to which the FAA prescribed tests will correlate with the UL tests is not likely to be high. The dry (i.e., fuel not floating on water) pool tests allow the fuel to run onto a concrete pad and spread over the surface. The resulting pool is not very deep. The UL tests are run in a specific size pan with much deeper fuel. The deeper fuel of the UL tests may allow the fire to burn at steady state with a much higher fire intensity than the spreading fuel tests. Although the fires represented in the FAA series prescribe a particular area of fire coverage, e.g., 800 ft^2, there is no direct correlation with the UL tests. The 800 ft^2 dry pool fire in these tests does not in any way indicate that the extinguisher would meet the UL 320B rating (800 ft^2 in-depth fuel pan fire).

8.2 FAA Requirements for Halon 1211 Alternatives

As stated previously, the analysis performed by the FAA shows that the original decision to require 500 pounds of Halon on CFR vehicles was based more on the weight of agent that could be carried by a ¾ ton pick-up truck than any operational requirement [Wright, 1995]. They also report that the average quantity of Halon 1211 used by the USAF and Navy between 1992 and 1994 was 109 pounds, but no reference was provided. They reported that the 109 pound value correlated well with the original premise that 100 pounds of Halon 1211 was required.

The FAA has approved Halotron I as an acceptable alternative to Halon 1211. In making this determination they based their assessment on the USAF and FAA tests where 1.5 pounds of Halotron I was deemed to be equivalent to 1 pound of Halon 1211 [Wright, 1995]. They argue

that at a ratio 1.5 pounds of Halotron I to 1 pound of Halon 1211, 165 pounds of Halotron I correlates to the 109 pounds of Halon 1211 that the U.S. military reported as average use of Halon 1211 for extinguishing a flight line fire. The 165 pounds derived from the equivalency ratio correlates well with their assessment of the results from their tests.

The tests using Halotron I were limited to direct drop-in of the agent into the existing Halon 1211 150 pound extinguishers [Wright, 1995]. Eighty one tests were performed. They reported that 28 were fully extinguished requiring on average 115 pounds of Halotron I, but it appears based on their graphical results presented that 32 fires were extinguished. Of the 32 fires extinguished, two required more than 150 pounds of Halotron I: (1) between 225-250 pounds and (2) 325-350 pounds. Twenty-eight fires were brought under control requiring an average of 144 pounds of Halotron I and a maximum of 188 pounds. They estimate that all fires could have been extinguished with only a small quantity of additional agent, but they never verified this assumption. Based on this assessment, they estimate that all of the test fires would have been extinguished with 250 pounds of Halotron I. Using the equivalency ratio of 1.5 to 1, they estimate that 500 pounds of Halotron I on a CFR vehicle would provide a safety factor of 2.0 times that needed to extinguish all of their test fires. They also indicated that all non-military airports that use Halon 1211 containing CFR vehicles also have dry chemical vehicles available. Therefore, no airport solely relies on Halon 1211 to meet the agent requirements. Based on this fact and the agent quantity tests, the FAA approved the use of Halotron I to meet FAA requirements for Halon 1211.

8.3 FAA Versus Navy Requirements

There are several differences between the FAA and the DoD relative to the regulation and use of firefighting equipment. The first is that the FAA does not prescribe a single approved agent for use, but instead provides a total list of acceptable agents. This difference in part is due to their different functions. The FAA does not have the legal authority to require one agent over another. Their authority ends at establishing a minimum acceptable level of safety. Secondly, the FAA is not responsible for the logistical functions for developing, purchasing, stocking and

provisioning. The military is responsible for all of these other factors, and in part, they drive decisions on what is or is not acceptable.

While the FAA considers foams as the primary agent for aircraft CFR operations, the draft Advisory Circular still recognizes the use of protein foam, fluoroprotein foam, AFFF, and Film Forming Fluoroprotein (FFFP) foam as acceptable foam agents [FAA, undated]. Since at least 1983, the NATOPS recognizes only AFFF as the primary agent [NATOPS, 1983; NATOPS, 1994]. A second example is in the use of Halon 1211. For the most part, the Navy replaced the PKP internal systems on CFR systems (e.g., P-19, P-16, TAU-2) with Halon 1211. Unlike the FAA regulated facilities where PKP is believed to be always present, on military flight lines Halon 1211 may be the only secondary agent available. The presence of other agents on FAA facilities creates a major difference in operational requirements. The FAA facilities are less worried about collateral damage issues than safety of the passengers on the aircraft [Leach, 1996b]. PKP and AFFF would be used on a commercial aircraft about as easily as Halon 1211. The important issue is to get the fire out to safe guard the passengers. Unlike the military aircraft that may extinguish a fire with a clean agent and immediately take-off, the commercial airlines are much more conservative. At a minimum, the component would be inspected and is likely removed and replaced. The down-time associated with a dirty agent versus a clean agent is not very different under these circumstances. While it might be considered advantageous to limit or eliminate collateral damage, it is not the hard driver as it is in military aircraft.

There are also significant differences in operating conditions on the flight deck versus a flight line that may affect the overall performance of PKP versus Halon 1211. For example, there is always a significant wind on the flight deck that may carry the agent to other aircraft. This is exacerbated by the higher density of aircraft present on flight decks. Damage to an aircraft on board ship presents logistical impacts because each ship must carry whatever spare parts that it needs. Damage to several aircraft simultaneously could create severe operational impacts. These logistical and operational differences translate to different firefighting needs between the Navy and the FAA.

Another difference in requirements is in the case for Class A effectiveness. In additional to electrical fires where wire bundles and circuit boards catch on fire and wheel/brake fires where tires may catch on fire, military aircraft have composite components that fall into the Class A category. The more extensive use of composites on the F/A-18/E/F and the predominant use of composites on the new aircraft such as the Joint Strike Fighter (JSF) and the F-22 increases the issues for Class A capabilities. The tests required by the FAA were not designed to address this requirement because there are no commercial composite aircraft. This is a significant departure in operational requirements that the FAA test series will not address for the military. An additional test or tests may need to be performed above those of the FAA to adequately address this requirement.

9.0 U.S. MILITARY FIRE INCIDENTS

It is not possible to derive specific, quantitative, operational and technical requirements used to determine agent quantities and system requirements from the NATOPS, the historical development of Halon 1211 systems and the FAA work. In order to quantify the Navy aviation firefighting needs, two sets of Naval Safety Center data were reviewed. These data are for fire incidents reported by the facilities fire departments. The first set of Naval Safety Center data is from a previous study performed by NRL for the USAF to evaluate the need for a clean, secondary agent versus the need for an effective non-clean secondary agent, i.e., Halon 1211 / alternative versus PKP [Leonard et al., 1992]. The data include all Navy reported incidents from 1977 to 1991 and all reported USAF incidents from 1981 to 1991. The second set of Naval Safety Center data includes all reported incidents using Halon 1211 for Fiscal Years 1993-1995, for the Army, Navy, USAF and USMC. Data were also requested for FY 96 to the present. However, the Naval Safety Center was changing the reporting system, and the available data were not complete. Based on the scarcity of events reported in 1995 to present, it was decided that the data from the new reporting system would not be included in this evaluation.

9.1 Reported Fire Incidents: Navy 1997-1991; USAF 1981-1991

The intent of the analysis performed for the previous USAF study was significantly different than for this one. However, some of the analyses and the data are useful in this study. The database that was created for the previous study was re-evaluated to provide additional information important to this study. The USAF reported 515 fire incidents over the 11 year period (1981-1991), and the Navy reported 380 fire incidents over the 15 year period (1977-1991), yielding a combined total of 895 reported incidents. The previous work found that dollar loss estimates for these incidents fell into two distinct groups [Leonard et al., 1992]. The high dollar loss incidents averaged $1,405,337 per incident and were defined as large fires. The average dollar loss for the remaining fires was $12,060 per incident. These fires were classified as either small fire or no-fire events as illustrated in Table 2. For this study, the small and no-fire events are combined and reported as small fires. It is recognized that dollar loss does not directly translate to fire size. However, in the absence of direct data on fire size, the dollar loss data does provide some indication of the severity of the event. This limitation should be considered throughout the following discussion. The frequency of extinguishing agent use based on the size of the fire is provided in Table 3. Halon 1211 is the predominant agent used, followed by AFFF, CO_2, water and PKP. AFFF and water were most frequently used in large fires, approaching two-thirds of the incidents.

Table 2. Distribution of 1977-1991 Incidents for Navy and USAF Based on Fire Size [Leonard et al. 1992]

	Large	Small	Total
USAF	35 (71 %)	480 (57 %)	515 (58 %)
Navy	14 (29 %)	366 (43 %)	380 (42 %)
Total	49 (5 %)	846 (95%)	895 (100 %)

Table 3. Distribution of Firefighting Agent Reported in 1977-1991 Incident Data Based on Fire Size [Leonard et al., 1992]

	Large Fires	Small Fires
Halon 1211*	15 (29 %)	529 (57 %)
CO_2	3 (6 %)	103 (11 %)
PKP	3 (6 %)	65 (7 %)
AFFF	27 (53 %)	158 (17 %)
Water	3 (6 %)	69 (7 %)

* Likely primary agent

Of the total 895 reported incidents, 672 (75%) were aircraft related, and 223 (25%) were non-aircraft related [Leonard et al., 1992]. The incident data were also analyzed for fire type. As illustrated in Table 4, the aircraft incidents fall into 4 basic areas: (1) engine, (2) fuel spill, (3) wheel/brake and (4) electrical fires. "Engine" fires include incidents for engines, starters, nacelles, wet starts/tailpipe and fuel leaks. The majority of the aircraft fires are engine fires representing 47 percent of the incidents. Wheel/brake fires and fuel spills represent 16 percent each, and electrical fires represent approximately 12 percent of the aircraft fires. The remainder were categorized as miscellaneous or were not identified. As illustrated in Table 5, two-thirds (446) of the aircraft incidents involved the use of Halon 1211, 25 of the 35 large fires and 421 of the 637 small fires.

Table 4. Distribution of Fire Types Reported in 1977-1991 Incident Data Based on Fire Size [Leonard et al., 1992]

	Large	Small	Total
Non Aircraft	14 (29 %)	209 (25 %)	223 (25 %)
Engine/Nacelle	9 (18 %)	178 (21 %)	187 (21 %)
Cold Start	2 (4 %)	92 (11 %)	94 (11 %)
Electronics/Avionics	2 (4 %)	75 (9 %)	77 (9 %)
Wheel/Brake	1 (2 %)	103 (12 %)	104 (12 %)
Fuel Spill	2 (4 %)	107 (13 %)	109 (12 %)
Fuel Leak/Debris	7 (14 %)	24 (3 %)	31 (3 %)
Exposure Fire	1 (2 %)	2 (0 %)	3 (0 %)
Miscellaneous	11 (22 %)	56 (7 %)	67 (7 %)

Table 5. Distribution of Fire Incidents (1977-1991) Where Halon 1211 Was Used by Service

	Navy	USAF	Total
Aircraft Large Fire	4 (16 %)	21 (84 %)	25
Aircraft Small Fire	150 (36 %)	271 (64 %)	421
Non Aircraft Large Fire	- (0 %)	4 (100 %)	4
Non Aircraft Small Fire	19 (25 %)	58 (75 %)	77

Table 6 provides the distribution of events based on the use of Halon 1211 as the primary or secondary agent. Halon 1211 versus other agents was used 85 percent of the time to extinguish engine fires, 89 percent for large fires and 85 percent for small fires. The use of Halon 1211 for engine fires represents 56 percent of the total Halon 1211 use. Of the total 16 engine large fires where Halon 1211 was used, it was used seven times (44%) as the primary agent and nine times (56%) as the secondary agent. For the 249 engine small fires where Halon 1211 was used, it was used 233 times as the primary agent (94%) and 16 times (6%) as the secondary agent.

Table 6. Distribution of Aircraft Fires (1977-1991) by Use of Halon 1211 and Use as Primary or Secondary Use by Fire Type

	Engine	Spill	Electrical	Wheel/Brake	N/A
25 Large Fires					
Primary	7	1	1	–	3
Secondary	9	1	–	–	3
Subtotal	16 (64%)	2 (8%)	1 (4%)	–	6
421 Small Fires					
Primary	233	2	48	78	35
Secondary	16	–	–	–	3
Subtotal	249 (56%)	2 (0.5%)	48 (11%)	84 (19%)	38
446 Total Incidents (using Halon 1211)	265 (56%)	4 (1%)	49 (11%)	84 (15%)	44
Total fire Incidents	312	109	77	104	70
Percent Using Halon 1211	85%	4%	64%	81%	63%

Halon 1211 was also the predominant agent used for wheel/brake fires, representing over 80 percent of agent use. Only one wheel/brake incident was responsible for a large fire. Halon 1211 was not used in that incident. Of the 84 incidents with Halon 1211 for wheel brake fires, it was used 78 times (93%) as the primary agent and 6 times (7%) as the secondary agent. The use of Halon 1211 for wheel/brake fires represents 19% of total Halon 1211 use.

For electrical fires, Halon 1211 was used for nearly two-thirds of the events and in one of the two large fires. When Halon 1211 was used for electrical fires, it was used only as the primary agent. The use of Halon 1211 for electrical fires represents 11 percent of the total Halon 1211 use.

Halon 1211 was rarely used for spill fires, representing less than 5 percent of agent use. It was used as the primary agent in both spill small fires and in one of the two spill large fires. The use of Halon 1211 for spill fires represents only 1 percent of the total Halon 1211 use.

Overall, Halon 1211 was used as the primary agent in 12 of the 25 large fire incidents and the secondary agent in the remaining 13. The USAF accounted for all 13 uses of Halon 1211 as the secondary agent in large fires. For small fires, Halon 1211 was used as the primary agent nearly 95 percent of the time

The predominant use of Halon 1211 as the primary agent for engine, wheel/brake, and electrical fires was expected for two reasons: (1) Halon 1211 is the agent available to the flight line crew for first attack, and (2) the use of other agents is believed to cause significant collateral damage, with the possible exception of CO_2 where thermal shock and static discharge are a lesser concern. The very low use for Halon 1211 with fuel spills was also expected. AFFF is the primary agent for 2-D, Class B fires. The use of Halon 1211 as the secondary agent for one of the two fuel spill, large fires may be the result of the firefighters using all available agents to combat the fire and not because of its capabilities as a clean, 3-D agent.

The distribution of incidents using Halon 1211 based on the application method, e.g., hand held, flight line extinguisher and CFR vehicle is provided in Table 7. For large fires, the CFR vehicle is the predominant application method representing 80 percent of the total agent use. Hand held extinguishers were not used at all for large fires. For small fires, flight line extinguishers are used nearly 50 percent of the time and CFR vehicles approximately 30 percent of the time. The predominant use of the flight line extinguisher for small fires is expected. These extinguishers are the most likely available to the crew and maintenance staff for immediate use on a fire. The extensive use of Halon 1211 from CFR vehicles was more surprising. The USAF was much more likely to use the CFR vehicle to dispense Halon 1211 than the Navy, 92% and 8% respectively.

Table 7. Distribution of Aircraft Fires (1977-1991) using Halon 1211 Based on Application Method and Fire Size

	Hand held	Flight line	CFR Vehicle	N/A
25 Large Fires				
12 Primary	-	4	8	
13 Secondary	-	1	12	
421 Small Fires				
396 Primary	96	185	107	8
25 Secondary	8	3	14	

The quantities of Halon 1211 reported as used in the incident data are provided in Tables 8 and 9 for the large fires and small fire respectively. As illustrated in Tables 8 and 9, a qualitative correlation exists between the quantity of Halon 1211 reported and the size of the fire. All of the large fire incidents reported at least 51 pounds of Halon 1211. Quantities in excess of one 150 pound unit (i.e., 151 pounds and higher) were reported nearly 75 percent of the time in large fires versus less than 25 percent in small fires.

As illustrated in Table 9, a fairly even distribution of quantities of Halon 1211 was reported for small engine fires. A different result is obtained when the quantities of agent in a particular system are taken into consideration. It must be noted that the analysis is limited to the extent that it can compare one system to another. The analysis does not account for agent flow rates and throw capabilities which will significantly affect the extinguishment capability. Further, it does not take into account the ultimate effectiveness of whether the fire was extinguished by that quantity of agent. The analysis does, however, provide some indication of the severity of the fires encountered by the field and the requirements for extinguishment. On an agent quantity basis, 29 percent of the engine fires could be extinguished by the quantities contained in a 20 pound Halon 1211 extinguisher, 45 percent could be extinguished with a single 150 pound unit (or potentially with several 20 pound portables), and 22 percent required quantities contained in a CFR vehicle (or potentially several 150 pound units). The remaining 4 percent of engine fires required more Halon 1211 than carried by a single CFR vehicle.

Table 8. Distribution of Aircraft Large Fires (1977-1991) Using Halon 1211 Based on Fire Type and Quantity of Agent Reported As Used

	Quantity (lb)	Engine	Spill	Electrical	Wheel/Brake	N/A
12 Primary	1-20					
	21-50					
	51-100	1 (6 %)				1 (17 %)
	101-150					
	151-500	4 (25 %)		1 (100 %)		2 (33 %)
	> 500	1 (6 %)	1 (50 %)			
	N/A	1 (6 %)				
13 Secondary	1-20					
	21-50					
	51-100	1 (6 %)				
	101-150	2 (13 %)				
	151-500	2 (13 %)	1 (50 %)			1 (17 %)
	>500	4 (25 %)				2 (33 %)
	N/A					

Table 9. Distribution of Aircraft Small Fires (1977-1991) Using Halon 1211 Based on Fire Type and Quantity of Agent Reported as Used

	Quantity (lb)	Engine	Spill	Electrical	Wheel/Brake	N/A
396 Primary	1-20	66 (27 %)	1 (50 %)	29 (60 %)	28 (33 %)	11 (29 %)
	21-50	16 (6 %)	1 (50 %)	6 (13 %)	9 (11 %)	4 (11 %)
	51-100	43 (17 %)	-	4 (8 %)	4 (5 %)	8 (21 %)
	101-150	52 (21 %)	-	8 (17 %)	13 (15 %)	8 (21 %)
	151-500	48 (19 %)	-	1 (2 %)	15 (18 %)	4 (11 %)
	> 500	8 (3 %)	-	-	9 (11 %)	-
25 Secondary	1-20	6 (2 %)	-	-	1 (1 %)	2 (5 %)
	21-50	1 (<1 %)	-	-	-	1 (3 %)
	51-100	-	-	-	1 (1 %)	-
	101-150	1 (<1 %)	-	-	-	-
	151-500	6 (2 %)	-	-	3 (4 %)	-
	> 500	2 (1 %)	-	-	1 (1 %)	-

The majority of the electrical fires (60%) were extinguished by 20 pounds or less of Halon 1211. Taking into account the quantities of agent in a system, with the same limitations discussed above, these fires could be extinguished by a single 20 pound portable extinguishers. In only one case did extinguishment require more Halon 1211 than carried on a single CFR vehicle. The remaining 18 events could be extinguished with quantities contained in a single flight line extinguisher.

The results for wheel/brake fires are different than for the previous two cases. On a quantity basis, one-third of the fires required 20 pounds or less of Halon 1211 and 29 percent required 151 or more pounds of Halon 1211. This suggests that the fire is either easily extinguished with a small quantity of Halon 1211 or requires a fairly large quantity.

No significant difference exists between the quantities of Halon 1211 used as a primary agent or as a secondary agent in extinguishing large fires. A similar result is found between quantities of Halon 1211 used as the primary agent versus the secondary agent for small fires. Small quantities, 20 pounds and less, and large quantities, greater than 150 pounds of Halon 1211, are used for engine and wheel/brake fires.

9.2 Reported Fire Incidents: 1992-1995

A request was made to the Naval Safety Center to obtain the fire incident data for the period 1992 to the present. The following data were requested from the new reporting system [NRL, 1997; Verdonik, 1997]:

- Aerospace, by service where Halon 1211 was used;
- Quantity;
- Primary/secondary (if secondary what was primary);
- Type of situation (fire type);
- Type of equipment / extinguisher;
- System (Make and Model);
- Damage (property?);
- Who used it? How applied?;
- Narrative – ARFF;
- Delay "response" and time crash;
- Situation area;

- Response time (Time line);
- Hot spot arrived;
- Date / 1st Agent Time; and
- Time extinguished.

It was reported by the Naval Safety Center that the data from the new reporting system was not providing complete information [Lisa, 1997]. It was decided to collect the data from the old reporting system that went off line at the end of FY 95. The data entry fields in the old reporting system are not the same as for the new reporting system. Therefore, the data received were not exactly as originally requested. The following data fields were supplied from the old reporting system:

- Service,
- Arrival Date,
- Arrival Time,
- Event Date,
- Time Unit Cleared,
- Type Situation Found (By Category),
- Fiscal Year,
- Extinguishing Agent (By Category),
- Extinguishment Quantity,
- Extinguishment Unit of Measure (By Category),
- Method of Extinguishment (By Category), and
- Reportable Event Narrative.

A total of 219 incidents of Halon 1211 use were reported by the Army, Navy, USMC, USAF, and "other" fire departments for FY 93 - 95. An example of an incident report is provided in Appendix B [NSC, 1997]. A review of the 219 reports indicated that 15 were incorrectly reported as Halon 1211. The onboard systems containing Halon 1301, Halon 1202 and Halon 1011, and the Halon 1301 hand helds were sometimes reported as Halon 1211. These 15 reports were removed from the analysis.

The Reportable Event Narrative section for the remaining 204 reports were reviewed to determine the following additional information:

- type of fire/event,

- fuel (substance burning),
- use as primary or secondary agent,
- type of system(s) used (i.e., CFR vehicle, flight line extinguisher, and hand held (by size)),
- quantity of agent from each system,
- success or failure of each system, and
- personnel responsible for extinguishing the fire.

In some cases, all of the data were not present and could not be determined.

As illustrated in Table 10, the USAF reported more than half (53%) of the total fire incidents that used Halon 1211. The Navy and USMC represents the majority of the remaining events, 31 percent and 13 percent respectively, yielding a combined total of 44 percent. The Army has the fewest reported incidents using Halon 1211, representing only 2 percent of the total.

Table 10. Incidents from 1992-1995 by Service

Service	Events	Events/Year
USAF	107 (52 %)	36 (53 %)
Army	6 (3 %)	2 (3 %)
USMC	26 (13 %)	9 (13 %)
Navy	64 (31 %)	21 (31 %)
Other	1 (<1 %)	<1 (<1 %)
TOTAL	204	68

The low incident rate for the Army may be a result of the type of aircraft used. The Army has more total aircraft than the USAF, Navy, or the USMC. On a number of aircraft basis, it might be expected that the Army would have an equivalent share of engine fire incidents. However, the Army has helicopters, observation aircraft, and small courier aircraft. None of which have augmenters (after burners). The after burner may be an important contributor to the frequency of fighter/attack aircraft engine fires. The low incident rate for Army aircraft lends support to this assertion; however, the Army also had a lower incident rate for electrical fires than would be expected based on aircraft quantities. It is also possible that the reporting from the Army is not as complete as those from the other services. In addition, the Army did not fully field

the Halon 1211 flight line units. Significant quantities of CO_2, PKP and foam extinguishers may still be found on Army flight lines. The incident rates for events using Halon 1211 for the other three services appears to be in line with the quantities of aircraft owned.

As shown in Table 11, the overwhelming majority of the reported incidents fall into three basic categories: engine (61%), wheel/brake (23%) and electrical (8%) fires. The remaining incidents for crashes, fuel tank spills and other miscellaneous fires represent only 8 percent of the total reported incidents. The results for these incident reports are consistent with the older incident reports previously reported in Table 6. These three fire types make up 92 percent and 86 percent of the total incidents for the FY 93-95 incident data and the previous incident data respectively. The engine fires were also categorized by the specific component that caused or were involved in the fire: (1) engine, (2) Auxiliary Power Unit (APU), (3) starter and (4) gear box. As illustrated in Table 11, the engine itself is involved in more than half of the total engine events. The starter is involved in over one quarter of the events and the APU is involved in the majority of the remainder.

Table 11. Distribution of FY 93-95 Incidents by Fire Type

INCIDENT TYPE		EVENTS
CRASH		9 4%
ELECTRICAL		17 8%
ENGINE		125 61%
COMPONENT	EVENTS / %	
ENGINE	68 54%	(33%)
APU	20 16%	(10%)
STARTER	35 28%	(17%)
GEAR BOX	2 2%	(1%)
WHEEL/BRAKE		46 23%
FUEL TANK		2 1%
MISCELLANEOUS		5 2%

The engine, APU and starter fires were analyzed to determine the cause of the fire. Of the total 125 engine fires, 30 did not contain enough information to positively determine the cause of the fire. For the remaining 95 engine incidents, approximately 75 percent are small fires resulting from wet starts, shutdown of the engine, small leaks and no fire events, e.g., smoke but no evidence of fire. When reported, it was typical for the agent to be directed at the tail pipe/exhaust. In three of the events, the narrative indicated that Halon 1211 was directed into the intake, two for the engine and one for the Jet Fuel Starter (JFS). The majority of the remaining 25 percent of the identifiable causes were due to mechanical failure where the potential for a large fire developing is high. Only one nacelle fire was reported.

Table 12 provides the distribution of events based on the quantity of Halon 1211 used as the primary or secondary agent by fire type. As can be seen, the majority of the events use Halon 1211 as the primary agent. It was used as the secondary agent only three times. This result is not the same as for the older incident data where Halon 1211 was used nearly 10 percent of the time as the secondary agent. The 1977-1991 incident data indicated that the USAF was responsible for (1) 92 percent of the reported use of Halon 1211 from CFR vehicles and (2) all of the use of Halon 1211 as a secondary agent for large fires as compared to (1) 12.5 percent and (2) 67 percent for the 1992-1995 data, respectively. The USAF removed Halon 1211 from internal tanks of USAF CFR vehicles in the 1992 time frame which may account for much of this difference.

Table 12. Distribution of Aircraft Incidents (FY 1993-1995) using Halon 1211 Based on Fire Type and Quantity of Agent Used as Primary or Secondary Agent

	Quantity (lb)	Crash	Spill	Engine	Electrical	Wheel/Broke
Primary	1-20	2 (22 %)	1 (33 %)	26 (22 %)	9 (56 %)	17 (37 %)
	21-50	1 (11 %)		23 (19 %)	3 (19 %)	6 (13 %)
	51-100	1 (11 %)		30 (25 %)	1 (6 %)	4 (9 %)
	101-150	1 (11 %)		23 (19 %)	2 (13 %)	9 (20 %)
	151-500	2 (22 %)		18 (15 %)	1 (6 %)	10 (22 %)
	> 500	-	1 (33 %)	-		
Secondary	1-20					
	21-50					
	51-100					
	101-150					
	151-500					
	> 500	1* (11 %)	1** (33 %)			
	N/A	1 (11 %)				

* Brush Fire

** Used to control fire until AFFF could be applied.

Consistent with the results for the old incident data, a fairly even distribution of quantities of Halon 1211 was reported for engine fires. Using the same consideration for quantities of agents in a particular system and the limitations of the analysis previously described, 21 percent of the engine fires could be extinguished with quantities in a 20 pound Halon 1211 extinguisher, 63 percent could be extinguished with the quantities in a flight line unit and 15 percent required the quantities on a CFR vehicle. One incident did not provide agent quantities.

The results for electrical and wheel/brake fires are also consistent with the previous incident data. More than half of the electrical fires were extinguished with 20 pounds or less of Halon 1211. On a system basis, all but one of the remaining electrical fires could be extinguished with the quantities of a single flight line extinguisher. For wheel/brake fires, more than one-third

were extinguished with less than 20 pounds of Halon 1211 and more than 20 percent required the quantities of Halon 1211 contained in a CFR vehicle.

For crash fires, Halon 1211 was used as the primary agent seven times ranging from 5 to 907 pounds. Halon 1211 was used once as the secondary agent to water using 500 pounds. This use is likely the result of the firefighters using all available agents to combat the fire than any unique capabilities of Halon 1211. For the fuel tank spill that resulted in a pool fire, 1050 pounds of Halon 1211 were used.

As noted previously, two important limitations exist with the quantity of agent reported in the incident data. First, the quantity of agent by itself does not directly indicate whether or not that quantity of Halon 1211 was successful in extinguishing the fire. Second, the quantity data are a compilation of the total quantity of Halon 1211 reported for all Halon 1211 systems and do not take into account the effectiveness of a particular system. Therefore, the agent quantity data used by itself can be misleading. To resolve these limitations, the narratives provided in this set of data (FY 1993-1995) were reviewed to determine (1) the effectiveness of each Halon 1211 system used in a particular incident, (2) who was responsible for extinguishing the fire (i.e., CFR staff versus maintenance/crew), and (3) the use of Halon 1211 versus the other agents.

10.0 USE OF HALON 1211 BY SYSTEM AND PERSONNEL

The distribution of incidents using Halon 1211 based on the application method/system, e.g., hand held, flight line extinguisher (150 pound wheeled unit) and CFR vehicle versus fire type is provided in Table 13. The system was not identified in 13 incidents and more than one system was used in six incidents, providing 197 identifiable system applications. Flight line extinguishers were used in the majority of the events, 147 times (75%). Two units were used together in 21 events representing 11 percent of the total incidents, three units together in four events representing 2 percent of the total incidents and seven units together in one event. Portable Halon 1211 extinguishers ranging from 2.5 pounds to 50 pounds were used in 34 incidents (17%). Two 20 pounds extinguishers were used together four times and four 20 pound extinguishers were

used together in one incident. Halon 1211 from internal supplies of CFR vehicles was only used in 16 (8%) of the total incidents.

Table 13. Distribution of Aircraft Incidents (FY 1993-1995) Using Halon 1211 Based on Application Method

	Crash	Spill	Engine	Electrical	Wheel/Brake	Other
Hand held	1	–	10	9	14	
Flight line	1	2	103	8	29	4
CFR Vehicle	5	–	8		3	
Unknown	2	–	5	2	3	1

Note: A single incident may report more than one application method.

The flight line extinguisher was used most often for engine fires, representing 52 percent of the total incidents and 70 percent of the use of the flight line extinguisher. The next most frequent uses were for wheel/brake fires and electrical fires representing 20 percent and 5 percent of the use of the flight line extinguishers respectively. The remaining 5 percent of flight line extinguisher use was for crash and spill fires or was not identified.

The use of hand held extinguishers was most frequent in wheel/brake fires representing 41 percent of their total use. Engine and electrical fires account for the overwhelming majority of the remaining hand held extinguisher use, 29 percent and 26 percent respectively. Halon 1211 from the CFR vehicle was only used in three fire types, 50 percent for engine fires, 31 percent for crash fires, and 19 percent for wheel/brake fires.

The distribution of incidents using Halon 1211 based on the type of personnel extinguishing the fire versus fire type is provided in Table 14. Of the 204 incidents using Halon 1211, maintenance personnel/crew were responsible for using Halon 1211 144 times and CFR staff 61 times. In five incidents, both the CFR staff and aircraft maintenance personnel/crew used Halon 1211, and in four incidents, the data were not provided. Although the CFR staff were

responsible for extinguishing 62 fires, the CFR vehicle was only used 16 times. CFR staff used the flight line extinguisher 28 times and portable extinguishers 16 times. In three incidents, the CFR staff used more than one system, and in five incidents, the system used by the CFR staff was not identified. CFR staff was much more likely to extinguish crash and spill fires. This finding was expected because these fires have the greatest potential to become large fires and the AFFF carried on the CFR vehicle is the most effective on 2-D pool fires. For the fire types that typically have potential to be small fires (e.g., engine, electrical, and wheel/brake), the flight line personnel were predominant in extinguishing the fire. Within the smaller fires, the highest number of incidents extinguished by the CFR staff was for wheel/brake fires. This was also expected based on the need for cooling of the wheel/brake assembly.

Table 14. Distribution of Aircraft Events (FY 1993-1995) using Halon 1211
Based on Who Extinguished the Fire and Fire Type

	CFR Staff	Maintenance/Crew	N/A
Crash	5	2	2
Spill	2		
Engine	29	99	1
Electrical	3	14	
Wheel/Brake	20	27	
Other	3	2	
Total	62	144	3

The predominant use of the flight line extinguisher was expected because it is the main one available for crew/maintenance personnel. However, the high use of the flight line unit by the fire department was not anticipated. The USAF CFR staff used the flight line extinguisher 17 times of the 21 times they used Halon 1211 and only used portable extinguishers twice. The Navy and USMC CFR staff used the flight line unit the remaining 11 times. The USMC CFR staff used hand helds five of the 15 times hand helds were used, the Navy CFR staff 6 of 22 times hand helds were used and the Army one of the three times hand helds were used. All three Halon 1211 systems are available to the CFR staff. The high use of flight line extinguishers is in part due to

the fact that the USAF removed the internal supplies of Halon 1211 from the CFR vehicles. The high use of the flight line extinguisher versus the portable extinguishers by the CFR staff is likely based on the higher extinguishment capability of the flight line unit versus the portable extinguishers. These results indicate that the CFR staff believes that they need a clean agent system with greater capabilities than hand helds.

11.0 EFFECTIVENESS OF HALON 1211 VERSUS OTHER AGENTS

Halon 1211 was not successful in extinguishing four engine fires. For these four fires, AFFF was used three times and dry chemical once to extinguish the initial fire or the reflash. In the three incidents where AFFF was used the quantity of Halon 1211 used (unsuccessfully) were 355, 300, and 150 pounds. All three are in the upper bounds for Halon 1211 quantities from flight line extinguishers. Halon 1211 is most effective against the small engine fires where the need to limit collateral damage due to the fire extinguishing agent is greatest. For larger fires, where the damage due to the fire outweighs the collateral damage potential from the extinguishing agent Halon 1211 is not as successful. This finding illustrates the requirement that (1) a 'clean,' secondary agent is needed to fight the engine small fires and (2) the effectiveness of the agent for engine large fires is more important than collateral damage concerns.

For the one electrical fire incident where more than 150 pounds of Halon 1211 was used, the 355 pounds of Halon 1211 was not successful in extinguishing the fire and was not an electrical fire. The incident involved the malfunction of a heater and ignited the heater fuel, i.e., Class B fire and was not an electrical fire. AFFF was used to successfully extinguish the Class B fire. As was the case for engine fires, this finding supports the requirement for a clean agent to minimize collateral damage for small electrical fires.

For wheel/brake fires Halon 1211 was unsuccessful in extinguishing the fire nearly 30% of the time. Water was used 13 times, AFFF twice, and dry chemical twice as the secondary agent. For the 10 cases where more than 150 pounds of Halon 1211 was used it was unsuccessful 4

times, 40%. Exactly 150 pounds of Halon 1211 was reported 7 times. Of those seven cases, Halon 1211 was unsuccessful 5 times.

11.1 Effectiveness of Halon 1211 Systems

The results based on success/failure are more dramatic for wheel/brake fires when the system effectiveness is also considered. Table 15 provides the success/failure rate for each Halon 1211 system based on fire type. Table 16 provides a further breakdown based on size of the hand held extinguisher. Table 17 provides the average quantity of Halon 1211 reported based on systems for each fire type. Hand held extinguishers were used 14 times, successfully in nine cases. Of the nine successful cases, a single extinguisher using 20 pounds or less of Halon 1211 was successful eight times. On the average, 7 pounds of Halon 1211 were used from a single extinguisher, and 50 pounds were discharged when two or more extinguishers were used.

A single flight line unit was used 19 times, 13 times successfully, averaging 77 pounds of Halon 1211. The 13 successful cases always used less than 75 pounds of Halon 1211. For the six unsuccessful cases, all 150 pounds in the flight line extinguisher was used in five cases. Two flight line units were used seven times, twice unsuccessfully. It is not clear from the fire incident data if these were used separately or in parallel. Three flight line units used together were unsuccessful all three times. In two of these three cases, all 450 pounds was used. It was not reported if they were used separately or in parallel. These results would seem to suggest that even large quantities of Halon 1211 are mainly ineffective on wheel/brake fires. However, the use of Halon 1211 from the CFR vehicle was effective in all three incidents, using between 100 and 125 pounds of agent. In one of these three cases where the CFR vehicle was used, 125 pounds successfully extinguished the fire where three simultaneous flight line units using 365 pounds of Halon 1211 could not. This suggests that system parameters such as flow rate and nozzle design are as important as agent quantities in determining system performance.

Table 15. Success/failure Rate of Halon 1211 Systems by Fire Type for FY 1993-1995 Incidents

	Crash	Spill	Engine	Electrical	Wheel/Brake
1 Hand held portable	1/0	-	6/3	6/2	9/3
2 Hand held portables	-	-	1/0	1/0	0/1
4 Hand held portables	-	-	-	-	0/1
1 flight line unit	0/1*	1/1	88/1	7/0	13/6
2 flight line units	-	-	12/2***	-	5/2
3 flight line units	-	-	-	0/1****	0/3
7 flight line units	-	1/0**	-	-	-
CFR vehicle	5	-	8	-	3

* Stopped extinguishment

** Effectively controlled until fire department responded

*** Re-flash occurred

**** Involved Class B fuel

Table 16. Success/failure Rate for Halon 1211 Hand Held Extinguishers by Fire Type for FY 1993-1995 Incidents

System	Crash	Spill	Engine	Electrical	Wheel/Brake
1 - 2.5 lb	-	-	2/1	2/0	1/0
1 - 5 lb	1/0	-	1/1	2/2	1/0
1 - 10 lb	-	-	-	-	1/1
1 - 14 lb	-	-	-	-	0/1
1 - 17 lb	-	-	0/1	-	-
1 - 20 lb	-	-	3/0	2/0	6/1
2 - 20 lb	-	-	1/0	1/0	0/2
4 - 20 lb	-	-	-	-	0/1
1 - 25 lb	-	-	-	-	0/1
1 - 50 lb	-	-	1/0	-	-

Table 17. Average Quantities of Halon 1211 Reported in FY 1993-1995 Incidents

Based on System versus Fire Type

	Crash	Spill	Engine	Electrical	Wheel/Brake	System Average
1 Hand held	5	–	7	6	7	7
2 or more hand helds	–	–	20	20	50	40
1 flight line	20*	10	79	60	77	69
2 or more flight lines	430	1050	194	355	299	275
CFR Vehicle	357	–	197	–	112	231
Fire type average	236	530	96	57	109	107

*Extinguishment stopped due to presence of ordnance.

The data on the successful and unsuccessful use of each system for wheel/brake fires adds further support to the finding that the fire is either easily extinguished with a small quantity of Halon 1211 from a hand held or flight line extinguisher or is not easily extinguished by these systems. The hand held and flight line extinguishers have the lowest success rate on wheel/brake fires compared to the other two predominant fire types (i.e., engine and electrical). The current capabilities do not provide for complete extinguishment of many wheel/brake fires but do provide for control of the incidents. The predominant use of Halon 1211 as the primary agent is likely the result of availability of the halon extinguishers and is not due entirely to its effectiveness. While the three cases where Halon 1211 was used from the CFR vehicle are the clear minority, they suggest that the flow rate of Halon 1211 may be a factor in its effectiveness on wheel/brake fires. Wheel/brake fires are caused by the build up of heat igniting residual grease or hydraulic fluid. Where the heat build up is minimal, Halon 1211 is capable of extinguishing the fire but would not provide extensive cooling. Higher flow rates from the CFR vehicle would provide additional cooling versus the flight line unit. This explanation is consistent with the NATOPS where cooling the wheel/brake assembly to prevent hot surface ignition and/or re-flash is the prescribed tactic.

The results on Halon 1211 system effectiveness for wheel/brake fires illustrate the need to consider system specific parameters and to not rely solely on agent quantities. For engine fires, hand helds were used ten times, seven successfully and three unsuccessfully, using an average of 7

pounds per incident. In the three unsuccessful events, 2.5, 5 and 17 pounds were used, each representing the full charge of the specific extinguisher. To extinguish those same fires, 10, 3, and 23 pounds were used from the flight line unit, respectively. In light of the fact that in the second case the quantity of Halon 1211 used to extinguish the fire was less than that used for unsuccessful extinguishment suggests that throw and/or flow rate may have been a factor in that incident. This is further supported by the third case where only a slightly higher amount of Halon 1211 was needed to extinguish the fires. A single 20 pound Halon 1211 extinguisher was used three times, and two 20 pound extinguishers were used in one incident always successfully. As expected, the higher success rate indicates that the 20 pound system capabilities (quantity, flow rate and throw) are better at meeting the threat than the smaller systems.

A single flight line unit was used in 89 engine events averaging 79 pounds of Halon 1211 per incident. One flight line unit was unsuccessful in only one case. Two flight line units were used together 14 times averaging 194 pounds of Halon 1211 per incident. They were successful 12 times and two re-flashes occurred. The CFR vehicle was used eight times averaging 197 pounds per incident, very nearly the same as the case for two flight line extinguishers. In only two cases was the CFR vehicle used in conjunction with a flight line extinguisher. It was not possible to determine if the fight line extinguisher was unsuccessful or used in conjunction with the CFR vehicle. The success rate of the flight line unit and the overall lack of combining the CFR capabilities with the flight line unit suggests that the flight line unit capabilities (e.g., quantity, flow rate and throw) generally meet or exceed the fire fighting needs for the majority of engine fires. For the larger engine fire threat, two flight line units generally meet or exceed the fire fighting needs.

For electrical fires hand held extinguishers were used nine times, twice unsuccessfully (>20 %), averaging 6 pounds of Halon 1211 per incident. Both unsuccessful cases used 5 pound units. Forty pounds from two 20 pound units were used to extinguish the fire in one case. In the other case, 145 pounds from one flight line unit were needed to extinguish the fire that involved both Class A and Class B material. A single 20 pound extinguisher was used in two events, both successfully. For electrical fires involving Class A material only, the 20 pound system capabilities

appear to better meet the threat than the smaller hand held units. When the electrical fire also involves a Class B material, the hand held extinguishers may not meet the threat.

A single flight line extinguisher averaging 60 pounds per incident was used in seven electrical fire events, always successfully. In the one case where three flight line extinguishers were used, 355 pounds of Halon 1211 was unsuccessful in extinguishing the fire that involved a Class B material. These results provide evidence that electrical fires involving only Class A material can be extinguished with the current hand held extinguisher capabilities. These results also provide further illustration of the requirement for a clean agent capable of extinguishing small fires to limit both fire and collateral damage. When electrical fires involve a Class B material, the need for effectiveness to quickly extinguish the fire, to limit fire damage, may outweigh the need to limit collateral damage from the agent.

Of the total of nine crash fires where Halon 1211 was used, a single 5 pound portable was used successfully in one incident to extinguish a small fire. Twenty pounds from a single flight line unit was used once, but the firefighting was halted due to the presence of ordnance. The firefighting threat from crashes can reasonably be expected to exceed the capabilities of hand held extinguishers. As shown in the data for nine crash fires, only one event used hand held equipment. Halon 1211 from the CFR vehicle was used five times, four successfully and once on a brush fire. For the fuel tank spill resulting in a pool fire, seven 150 pound units were used to control the fire, not extinguish it, until the fire department responded. Although the incident data did not indicate what agent was used by the fire department to extinguish the fire, based on the quantity of Halon 1211 used, they did not use Halon 1211. It is likely that AFFF was used. Consistent with the other fire types, Halon 1211 is needed for smaller fires to keep collateral damage to a minimum. Halon 1211 use for the large spill fire was the result of its availability in the flight line unit and not due to its unique capabilities. This illustrates the need for the flight line extinguisher to have some capability to control pool fires but does not indicate a requirement for extinguishment of large pool fires.

Table 18 provides the results for the average quantities of Halon 1211 reported for successful extinguishment. For the most part, the results are very similar to those using both

successful and unsuccessful extinguishment provided in Table 17. The most notable change is for spill fires where the average quantity of Halon 1211 is only 10 pounds per incident. The one large spill fire was not successfully extinguished by Halon 1211. The other significant change is for wheel/brake fires also resulting from the relatively high failure rate of Halon 1211 systems on wheel/brake fires.

Table 18. Average Quantities of Halon 1211 Used to Successfully Extinguish Fires Based on System versus Fire Type

	Crash	Spill	Engine	Electrical	Wheel/Brake	System Average
1 hand held	5	-	8	7	8	7
2 or more hand helds	-	-	20	-	40	26
1 flight line	-	10	78	60	51	75
2 or more flight lines	-	-	178	-	255	196
CFR Vehicle	357	-	197	-	112	231
Fire type average	259	10	97	42	70	98

11.2 Fire Incident Summary

The results on the types of fires from the 1977-1991 and FY 1993-1995 incident data are consistent with each other and the NATOPS. Small fires make up the over whelming majority of reported incidents. Small fires in the engine (engine, APU and starter), wheel/brake and electrical fires are the three most likely events needing response from flight line personnel. Consistent with the firefighting tactics provided in the NATOPS Halon 1211 is the most common agent used for these fires. For engine and electrical small fires, the data indicate the need for an agent that minimizes the potential for collateral damage. For wheel/brake small fires, incidents demonstrate the need to provide cooling for effective extinguishment.

Large fires make up a small portion of the fires, and a very small portion of the fires where Halon 1211 is used. The need to minimize collateral damage by the agent is greatly diminished by the need to extinguish the fire to limit overall damage. While large fires are a small portion of the

total incidents, they pose the greatest potential for loss and injury and, consistent with the NATOPS, are an important firefighting requirement.

The data based solely on agent quantities reported in the fire incidents can be misleading. The analysis based on system and agent quantities provides a better view of the effectiveness and needs for system capabilities. Portable extinguishers are unsuccessful 30 percent of the time. The 20 pound portable extinguisher had the highest success rate. Of its 15 uses, it was only unsuccessful twice, both times for wheel/brake fires. A single 20 pound extinguisher was used ten times, always successfully. In four of the unsuccessful portable uses, the flight line extinguisher successfully extinguished the fires; in several of these incidents, the quantities of Halon 1211 were less or comparable suggesting that flow rate and nozzle/spray characteristics are as important as agent quantity in the effectiveness of the system.

The flight line unit is the predominant system used by both crew/maintenance personnel and CFR staff. In part, this is due to their presence as the main system available on the flight line. Flight line extinguishers were only unsuccessful 11 percent of the time, of which three-fourths were due to wheel/brake fires. Discounting the wheel/brake fires, the flight line extinguishers were only unsuccessful in five incidents: (1) mechanical failure of the engine, (2) cargo hold fire, (3) large pool fire, (4) hydraulic leak and (5) heater malfunction with heater fuel fire. All five of these incidents have the potential to be considered large fires where the primary agent (AFFF/water) is the expected extinguishing agent.

On a system basis, the use of Halon 1211 from the CFR vehicle is the least likely representing only 8 percent of the total use of Halon 1211. This may be due to (1) size of fires, (2) types of fires, (3) effectiveness of the current flight line unit or (4) availability of the CFR vehicle. A part of this low frequency may be due to the removal of Halon 1211 from internal tanks of USAF CFR vehicles. Although the incident data may not indicate a significant use for large catastrophic events, the need for a secondary agent with three-dimensional capabilities is a requirement based on previous fire history, i.e., USS NIMITZ. These worst case scenarios do not happen often, but the CFR responders must maintain the capability should the event ever occur.

The need for a secondary agent for large catastrophic events has been demonstrated. The need for a "clean" agent for large catastrophic fires is questioned.

The analysis on system capabilities strongly suggests that any efforts to replace the current Halon 1211 extinguishers should not center only on the agent quantities but on the overall system capabilities. The fire extinguishing capabilities needed are considerably different for hand held extinguishers, flight line extinguishers and CFR vehicles. Hand held extinguishers are mainly needed for very small electrical and engine fires where the need to minimize collateral damage is high. Hand held extinguishers need to contain a clean agent. Hand held extinguishers need to be graded against limited size Class A and Class B fires and be suitable for Class C fires.

Flight line units are needed for small to medium size engine fires, e.g., wet starts, tail pipe fires and electrical fires that may also involve a Class B material. The engine fires are more than half of the total reported fire events. The need to limit collateral damage in these fires is also high. The flight line units need an agent that will not cause collateral damage to the engine or electrical components. The flight line units are also needed to extinguish the smaller wheel/brake fires, to control the 'larger' wheel/brake fires until the wheel/brake assembly can be cooled, to extinguish small pool fires and to control larger pool spills until the fire department responds with AFFF. The flight line unit needs to be graded against the engine and electrical fires and evaluated against the wheel/brake fires and small pool fires.

12.0 SHORE SIDE SYSTEM REQUIREMENTS

12.1 Engine Fires

At a minimum, the agent and system available to the flight line personnel must be able to extinguish small to medium 2-D and 3-D Class B engine fires without causing collateral damage. Capabilities to fight large 2-D and 3-D engine fires are a requirement but not for flight line personnel. The need to effectively extinguish the large fires to limit fire damage and prevent cook-off outweighs the collateral damage concerns. AFFF combined with a secondary agent for

the 3-D fires is adequate to meet this requirement. The need for large internal supplies of a clean, secondary agent on the CFR vehicle to fight engine fires is not apparent. Hand held and flight line extinguishers or TAUs might be adequate in meeting the secondary agent requirements. It is recommended that tests be performed to evaluate this possibility. The tests should include the currently fielded systems (Halon 1211, CO_2 and PKP) commercially available Halon 1211 alternative hand helds and developmental systems based on the commercially available agents. If the tests indicate the need for large internal supplies of a secondary agent on the CFR vehicles, PKP would meet this requirement. It is also recommended that the collateral damage concerns of PKP be resolved. If PKP were found to meet the collateral damage requirements, it would meet the firefighting requirements for engine fires in all three systems.

12.2 Wheel/brake fires

At a minimum, the agent and system available to the flight line personnel must be able to control small 2-D and 3-D Class A and Class B wheel/brake fires until the fire department responds. Flight line extinguishers that provide better cooling of the wheel/brake assembly would increase the capability in meeting this threat. While the requirement exists for an effective cooling agent on the CFR vehicle, water/AFFF meets this requirement. The need for large internal supplies of a clean, secondary agent on the CFR vehicle to fight wheel/brake fires is not apparent. As for the flight line units, hand held extinguishers that provide better cooling of the hot wheel/brake assembly would increase the capabilities but are not requirements. The flight line extinguishers and the water/AFFF available to the CFR staff are sufficient to meet this requirement.

12.3 Electrical Fires

At a minimum, the agent and system available to the flight line personnel must be able to extinguish small to medium electrical fires involving Class A materials without causing collateral damage. Commercially available CO_2 and Halon 1211 alternatives may meet the hand held requirements. Capabilities to fight electrical fires involving Class A and Class B fuels are a requirement similar to that for engine fires. The small and medium fires need a clean agent to

minimize collateral damage. It is recommended that CO_2 and commercially available Halon 1211 alternative hand held extinguishers be tested to determine if several used together or in series will meet this requirement. If they do not, developmental systems using the commercially available Halon 1211 alternatives should be tested for flight line units and TAUs. The need to effectively extinguish the large fires to limit fire damage outweighs the collateral damage concerns. AFFF combined with a secondary agent for the 3-D fires is adequate to meet this requirement. The need for large internal supplies of a clean, secondary agent on the CFR vehicle to fight electrical fires is not apparent.

12.4 Spill Fires

At a minimum, the agent and system available to the flight line personnel must be able to extinguish small and medium spill fires without collateral damage requirements. Current PKP hand held and wheeled extinguishers are expected to meet this requirement. The commercially available Halon 1211 alternatives may meet the hand held requirements. For the spill large fires, the requirement is met through the AFFF on the CFR vehicles and TAUs. No requirement exists for large quantities of internal supplies of a secondary agent on CFR vehicles to combat 2-D spill fires. When the spill also involves a 3-D fire, the same requirement as described for engine fires exists. AFFF combined with a secondary agent for the 3-D fires is adequate to meet this requirement. The need for large internal supplies of a clean, secondary agent on the CFR vehicle to fight large 2-D and 3-D fires is not apparent. Hand held and flight line extinguishers or TAUs might be adequate in meeting the secondary agent requirements on the flight line. If the tests indicate the need for large internal supplies of a secondary agent on the CFR vehicles, PKP would meet this requirement.

13.0 SHIPBOARD SYSTEM REQUIREMENTS

Of the fires types developed from the shore side incident data, all would be found on board ship except the wheel/brake fires. While the majority of the fire threats are the same, significantly different system capabilities are present ship board. On the flight deck, no flight line

extinguishers are available. The only sources of the secondary agent are the internal supplies on the P-16 which has been removed from the P-25, the TAUs and the PKP, CO_2 and Halon 1211 hand held extinguishers located at the AFFF hose stations, in the crash and rescue tools and on the P-25. Therefore, the system requirements are different. In particular, the requirements for the MFFVs versus the CFR vehicle are not comparable. The previous analysis indicating that large quantities of internal supplies of a clean secondary agent on the CFR vehicle do not hold for the P-16, P-25 and TAU-2Hs. The different system availabilities may also increase the firefighting requirements for the hand held portables.

13.1 Engine Fires

At a minimum, the agent and systems available to the flight deck personnel must be able to extinguish small to medium 2-D and 3-D Class B engine fires without causing collateral damage. CO_2 hand held extinguishers are still the most common on the flight deck and might be considered adequate to meet this requirement. However, the shore side fire incident data indicated that Halon 1211 hand helds were unsuccessful 30 percent of the time. The most effective Halon 1211 hand held was the 20 pound unit that likely has greater extinguishment capability than the current 15 pound CO_2 extinguisher. The flow rate and throw characteristics were also shown to be significant. The use of 7-foot extensions would solve the poor throw capabilities of the CO_2 unit, but the overall effectiveness is expected to be below the 20 pound Halon 1211 unit. When the requirement could not be met by the CO_2 Halon 1211 was available on the P-16 or TAU-2H. The use of the 20 pound Halon 1211 extinguisher on the P-25 appears to meet this requirement for the smallest fires. However, relying solely on Halon 1211 to meet the clean, secondary agent requirement is not recommended. At some point, Halon 1211 will not be available or its use may become restricted. It is recommended that alternative hand helds be tested to determine if they meet the clean, secondary agent requirements. The tests should include CO_2 and the commercially available Halon 1211 alternative hand helds. The clear majority of shore side engine fires used the flight line unit averaging 78 pounds per incident. It is not likely that hand helds will replace the majority of these events, but testing is needed to confirm this belief. A system containing a clean, secondary agent with increased capabilities versus the hand helds such as the P-16 and TAU-2H may be needed. This also reinforces the need to resolve the collateral damage

concerns of PKP. If PKP were found to meet the collateral damage requirements, it would meet the ship board firefighting requirements for engine fires.

Capabilities to fight large 2-D and 3-D engine fires are also a requirement. The need to effectively extinguish the large fires to limit fire damage and prevent cook-off of ordnance outweighs the collateral damage concerns. AFFF combined with a secondary agent for the 3-D fires is adequate to meet this requirement. As suggested for flight line engine fires, hand held extinguishers might be adequate in meeting the secondary agent requirements and tests are recommended to determine if this is true. The tests should include the currently fielded Halon Halon 1211, CO_2 and PKP hand helds and commercially available Halon 1211 alternative hand helds. If the tests indicate the need for larger supplies, greater flow rates and/or better throw the use of PKP for the P-16, P-25 and TAUs would meet this requirement for large fires.

13.2 Electrical Fires

At a minimum, the agent and system available to the flight deck personnel must be able to extinguish small to medium electrical fires involving Class A materials without causing collateral damage. Carbon dioxide hand held extinguishers are still the most common on the flight deck. The shore side fire incident data indicated that 5 pound Halon 1211 hand helds were unsuccessful 50 percent of the time, and 20 pound units were always successful. Commercially available CO_2 and Halon 1211 alternatives may meet the hand held requirements. Less than half of the shore side electrical fires used the flight line unit averaging 60 pounds per incident. It is possible that hand helds can be used successfully in many of these events. Testing is recommended to determine the extent of the fires that will not be adequately handled by hand helds and assess the collateral damage requirements for those cases. A system with a clean, secondary agent with increased capabilities versus the hand helds such as the P-16 and TAU-2H may be needed.

Capabilities to fight electrical fires involving Class A and Class B fuels are a requirement similar to that for engine fires. The requirements and recommendations for testing are essentially the same. Effectiveness for Class A/B fires will also need to be evaluated in the testing.

13.3 Spill Fires

For the small spill fires, the requirements are the same as for flight line fires. At a minimum, the agent and system available to the flight deck personnel must be able to extinguish small and medium spill fires with no concerns for collateral damage. Current Halon 1211 and PKP hand helds are expected to meet this requirement for the smallest spills. The commercially available Halon 1211 alternatives may also meet the hand held requirements. For the spill large fires, the requirement is met through AFFF hose lines and the MFFV. When the spill also involves a 3-D fire, the same requirement exists as previously described for engine fires. AFFF combined with a secondary agent for the 3-D fires is adequate to meet this requirement. The need for large internal supplies of a clean, secondary agent on MFFVs to fight large 2-D and 3-D fires needs to be tested. Hand held extinguishers might be adequate in meeting the secondary agent requirements on the flight deck. It is recommended that tests be performed using the debris pile to determine the best systems and tactics based on the current P-25 design and available secondary agent systems. The tests should include the current ship board hand helds (Halon 1211, CO_2, and PKP) and the commercially available Halon 1211 alternative hand helds. A system with increased secondary agent capabilities versus the hand helds such as the P-16 and TAU-2H may be needed. If the tests indicate the need for large internal supplies of a secondary agent on the MFFVs, PKP would meet this requirement.

14.0 SUMMARY AND CONCLUSIONS

The system requirements for aviation CFR operations on flight lines and flight decks were developed based on an analysis of the NATOPS, historical development of Halon 1211 systems and flight line fire incident data. The conclusions based on the findings of this study are as follows.

- Five main firefighting agents are currently used by the USMC and Navy: (1) AFFF, (2) water, (3) CO_2, (4) PKP and (5) Halon 1211. AFFF and water are the primary agents, and the remaining three are secondary agents used to increase the capabilities of the

primary agents. The agents are used in four types of firefighting systems, hand held extinguishers, flight line extinguishers, TAUs and CFR/MFFVs.

- The evolutionary nature of the NATOPS made it difficult to derive specific operational and technical requirements for agents, agent quantities and overall system needs.

- Anecdotal information was obtained on the historical development of the Halon 1211 systems. The agent quantities and capabilities of Halon 1211 systems were not developed based on developed operational requirements. Portable extinguishers were sized and optimized by industry to obtain Class A ratings needed to meet building codes. The 150 pound flight unit was developed based on using an off-the-shelf tank of similar size to the 10 gallon Halon 1011 extinguisher. Quantities on commercial CFR vehicles were based on a weight analysis of how much agent could be carried by a standard 3/4 ton pick-up truck, as has become the de-facto standard. The quantities on the P-16 and TAU-2Hs were based on the quantity of agent that would fit in the space previously used by PKP. No specific operational requirements could be derived from the available information.

- The 1977-1991 fire incident data indicated that aircraft incidents account for 75 percent of the total fire incidents reported by fire departments. The four most common flight line incidents are engine fires (47%), wheel/brake fires (16%), electrical fires (12%), and fuel spill fires (16%). Only a small percentage of the incidents, approximately 5 percent, resulted in large fires based on dollar loss data. AFFF and water were the predominant agent for large fires accounting for nearly two thirds of the incidents. Halon 1211 was the predominant agent for aircraft fires, particularly small fires. Halon 1211 was rarely used for spill fires. The FY 1993-1995 fire incident data for Halon 1211 events was consistent with the older incident data. The same four types of fires were found to be the most common: engine (61%), wheel/brake (23%), electrical (8%), and crash/spill fires (5%) and only a very small percentage of incidents resulted in large fires based on quantities of agent used. The results on fire types are also consistent with the expected fire types listed in the NATOPS.

- The need for a clean agent is demonstrated by the types and frequencies of the fires. The majority of the events are small fires where the collateral damage concerns are the greatest.

- Development of the firefighting requirements cannot be based solely on the reported quantities of agent. The analysis needs to incorporate the system effectiveness for each fire type. Any efforts to replace the current Halon 1211 extinguishers should not center on the agent quantities but on the overall system capabilities. The fire extinguishing capabilities needed are considerably different for hand held extinguishers, flight line extinguishers and CFR vehicles.

- The flight line unit is the predominant system used by both crew/maintenance personnel and CFR staff. In part, this may be due to their presence as the main system available on the flight line. Flight line extinguishers "failed" to extinguish the fires only 11 percent of the time. Three-fourths of the failed extinguishments were in wheel/brake fires. Discounting the wheel/brake fires, the flight line extinguishers were only unsuccessful in five incidents all with the potential to be considered large fires where the primary agent (AFFF/water) is the expected extinguishing agent.

- Flight line units are needed for small to medium size engine fires, e.g., wet starts, tail pipe fires, and electrical fires that may also involve a Class B material. Engine fires constitute more than half of the total reported fire events. The need to limit collateral damage in these fires is also high. The flight line units need an agent that will not cause collateral damage to the engine or electrical components. The flight line units are also needed to extinguish the smaller wheel/brake fires, to control the 'larger' wheel/brake fires until the wheel/brake assembly can be cooled, to extinguish small pool fires and to control larger pool spills until the fire department responds with AFFF. The flight line unit needs to be graded against the engine and electrical fires and evaluated against the wheel/brake fires and pool fires.

- On a system basis Halon 1211 from the CFR vehicle is used infrequently, representing only 8 percent of the total use of Halon 1211. The potential reasons are the (1) size of fires, (2) types of fires, (3) effectiveness of the current flight line unit and (4) availability of CFR equipment. A small part of this low frequency may be due to the removal of Halon 1211 from internal tanks of USAF CFR vehicles. Although the incident data may not indicate a significant use for large catastrophic events, the need for a secondary agent with three-dimensional capabilities remains a requirement. The need for this secondary agent to be clean is not apparent.

- Portable extinguishers were unsuccessful 30 percent of the time. The 20 pound portable extinguisher had the highest success rate. Of its 15 uses, it was only unsuccessful twice, both times for wheel/brake fires. A single 20 pound extinguisher was used ten times, always successfully. In four of the unsuccessful hand held uses, the flight line extinguisher successfully extinguished the fires; in several of these incidents, the quantities of Halon 1211 were less or comparable suggesting that flow rate and throw play as important a role as quantity in the effectiveness of the system.

- Hand held extinguishers are mainly needed shore-side for very small electrical and engine fires where the need to minimize collateral damage is high. Hand held extinguishers need to contain a clean agent. Hand held extinguishers need to be effective against limited size Class A and Class B fires and be suitable for Class C fires. For ship board use hand helds may need to have a greater effectiveness if they become the only source of a clean agent. Tests should be conducted on Halon 1211 and CO_2, and commercially available Halon 1211 alternative hand helds to determine their ability to meet the potentially increased ship board system requirement.

- Based on the difference in fielded systems ship board versus shore side, the system requirements for the same fire type may be different. Testing will be required to determine the best agents and ship board systems to meet the developed firefighting requirements. Further information on testing will be provided in Part IV – Halon 1211 Replacement Plan of this work.

15.0 RECOMMENDATIONS

The following studies and tests are recommended for the Halon 1211 Replacement Project. Further details will be provided in Part IV – Halon 1211 Replacement Plan of this work. (It must be noted that the results from some of the studies and tests may eliminate the need for additional tests.)

- It is recommended that a study be undertaken to evaluate the collateral damage of PKP. If PKP were found to meet the collateral damage requirements, it would meet the firefighting requirements for all fires types in all systems.

- Testing of hand held extinguishers using CO_2, 20 pound Halon 1211, (P-25 scenario) and Halon alternatives is recommended to determine the extent to which they can meet all of the clean agent requirements on the flight line and flight deck. Scenarios for engine, electrical, wheel/brake and spill fires need to be included. Specific tests and scenarios will need to be developed based on the developed requirements.

- Debris pile tests are recommended for evaluating the potential to use hand held extinguishers to supply the 3-D agent. Tests should be performed for PKP and Halon 1211 alternative agents.

If needed, it is recommended that 'clean' agents with 3-D capability be tested in larger systems than hand helds to determine their ability to meet both the clean agent requirements for small fires and the secondary agent requirements (i.e., 3-D Class B) for large fires (i.e., debris pile and engine). System considerations should include the current ship board systems, (i.e., P-16, TAUs, and P-25) and shore side flight line extinguishers based on the commercially available Halon 1211 alternative agents and, depending upon the results for PKP collateral damage issues, PKP. Specific tests will need to be developed based on the operational requirements and not the current performance of Halon 1211. Optimization of the system should be performed based on the expected fire scenarios. The tests should include small and large fires for engine, electrical,

wheel/brake, 2-D spills, and the 'standard' 2-D/3-D debris pile. Some scenarios will include pass/fail criteria for the minimum level of required performance. Other scenarios may be included to develop doctrine and tactics, and to provide firefighters with the limitations for the system.

16.0 REFERENCES

Burns, R.E. (1996), conversations with Robert E. Burns, Hughes Associates, Inc., Baltimore, MD, November-December 1996.

Carpenter, D.J, Verdonik, D.P., DiNenno, P.J., and Williams, F.W. (1997), "U.S. Navy Halon 1211 Replacement Plan: Part I - Development of Halon 1211 Alternatives," NRL Memo Report, in publication, 1997.

Carhart, H.W., Leonard, J.T., Darwin, R.L., Burns, R.E., Hughes, J.T., and Jablonski, E.J. (1987), "Aircraft Carrier Flight Deck Fire Fighting Tactics and Equipment Evaluation Tests," NRL Memorandum Report 5952, February 26, 1987.

Chambers, G.D. (1977), "Flight Line Extinguisher Evaluation," DOD-AGFSRS-76-9, Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, January 1977.

Darwin, R.L. (1996-1997), series of conversations with R.L. Darwin, Naval Sea Systems Command, Washington, DC, October 1996 - August 1997.

DDLA (undated), "Evaluation of the Use of Class I & Class II Ozone Depleting Substances," Report to Congress, Director of the Defense Logistics Agency, Department of Defense, Washington, DC.

FAA (undated), "Aircraft Fire Extinguishing Agents," Advisory Circular 150/5210-XX, Draft, Federal Aviation Administration, Washington, DC.

FAA 150/5210-6C (1995), "Aircraft Fire and Rescue Facilities and Extinguishing Agents," Federal Aviation Administration, Washington, DC, January 28, 1995.

Geyer, G.B., Neri, L.M., and Urban, C.H. (1978), "Full-scale Fire Modeling Tests of a Compact Rapid Response Foam and Dry Chemical Powder Dispensing System," FAA-RD-78-105, FAA Technical Center, Atlantic City, NJ, October 1978.

Geyer, G.B. (1982), "Equivalency Evaluation of Fire-Fighting Agents and Minimum Requirements at U.S. Air Force Airfields," DOT/FAA/CT-82/109, 1982.

Huston, P.O. (1996), telephone conversations with Paul O. Huston, Paul Huston and Associates, Trussville, AL, November-December 1996.

Leach, W. (1996a), "Navy Halon 1211 Replacement Program Proposed Statement of Work for 1996 Hughes Effort," NAWCADLKE, 24 July 1996.

Leach, W. (1996b), discussions with W. Leach, NAWCADLKE, December 1996.

Leonard, J.T., Budnick, E.K., Rosenbaum, E.R., Perrault, D.J., and Hayes, E.D. (1992), "Flightline Aircraft Fire Incidents and Suppression Agent Effects: Field Inquiries and Incident Analysis," Hughes Associates, Inc., Baltimore, MD, December 1992.

Lisa, V. (1997), series of conversations with V. Lisa, Naval Safety Center, Norfolk, VA, January - May 1997.

MCAS (1997), telephone conversations with USMC Aviation Fire Protection and Recovery Officers at MCA Quantico, VA; MCAS New River, Jacksonville, NC; MCAS Cherry Point, NC; MCAS Camp Pendleton, CA; MCAS El Torro, CA; MC Air Ground Combat Center, 29 Palms, CA; MCAS Yuma, AZ; MCAF Kanehoe Bay, HI; MCAS Tustin, CA; MCAS Iwakuni, Japan; MCAS Beaufort, SC; MCAS Futenma, Okinawa, Japan; March - June 1997.

Moore, D.W. (1996), conversation with D.W. Moore, The DuPont Company, Wilmington, DE, December 1996.

Nadolny, G. (1996), conversation with G. Nadolny, Ansul Incorporated, Marinette, WI, December 1996.

National Academy of Sciences (1997), Fire Suppression Substitutes and Alternatives to Halon for U.S. Navy Applications, Committee on Assessment of Fire Suppression Substitutes and Alternatives to Halon, Naval Studies Board, Commission on Physical Sciences, Mathematics, and Applications, National Research Council, National Academy Press, Washington, DC, 1997.

NATOPS (1983), "NATOPS U.S. Navy Aircraft Firefighting and Rescue Manual," NAVAIR 00-80R-14, Naval Air Systems Command, Washington, DC, 1 June 1983.

NATOPS (1994), "NATOPS U.S. Navy Aircraft Firefighting and Rescue Manual," NAVAIR 00-80R-14, Naval Air Systems Command, Washington, DC, 15 March 1994.

NATOPS (1996), "Final Conference Record," 1996 NATOPS Conference, U.S. Navy, Washington, DC, 16 October 1996.

NAVFAC (1996), "List of Navy CFR Equipment," Naval Facilities Engineering Command, Alexandria, VA, November 25, 1996.

NAWC (1997), Location of Hose Reels and Hose Valves on Flight Deck of USS Dwight D. Eisenhower CVN69, S0344 SM, Naval Air Warfare Center, China Lake, CA, March 25, 1997.

NFPA 10 (1994), "Standard for Portable Fire Extinguishers," National Fire Protection Association, Quincy, MA, 1994.

NFPA 403 (1988), "Standard for Aircraft Rescue and Fire Fighting Services at Airports," National Fire Protection Association, Quincy, MA, 1988.

NFPA 403 (1993), "Standard for Aircraft Rescue and Fire Fighting Services at Airports," National Fire Protection Association, Quincy, MA, 1993.

Novotny, J.J., Fletcher, N., and Ramsden, J. (1975), "An Evaluation of the Effectiveness of the FEU-1/M Model CB-10 Fire Extinguisher Converted for Use with BCF – Halon 1211," Contract F33657-75-C-0366, prepared for the U.S. Air Force, ICI United States, Inc., Wilmington, DE, 1975.

NRL (1997), "Fire Incident Data," letter to Commander, Naval Safety Center, Norfolk, VA, NRL Ltr Ser 6180/0011, 10 January 1997.

NSC (1997), "Selected Fire Responses Data," letter to D. Verdonik, Hughes Associates, Inc., Captain J.F. Boland, Naval Safety Center, Norfolk, VA, 5100 Ser 44/1126, 12 June 1997.

Rout, C. (1996), "Non-PAC Inventory Report," Atlantic Division, Naval Facilities Engineering Command, Transportation Equipment Management Center (Code 12), Norfolk, VA, 4 December 1996.

Rout, C. (1997), telephone conversations with Mr. Clarence Rout, Fire Marshal, Atlantic Division, Naval Facilities Engineering Command, Norfolk, VA, January 22, 1997.

SERD:P-16 (1996), "Support Equipment Recommendation Data (SE) – Consolidated Master SERD," NAWCADLKE, A/S32P-16A, U.S. Navy, Washington, DC, Data sheet approved August 23, 1996.

SERD:TAU-2H (1996), "Support Equipment Recommendation Data (SE) – Consolidated Master SERD," NAWCADLKE, TAU(H)-2, U.S. Navy, Washington, DC, Data sheet approved August 23, 1996.

Underwriters Laboratories Inc. (1995), *Fire Protection Equipment Directory*, Underwriters Laboratories Inc., Northbrook, IL, 1995.

USN (1997), "Navy Fact File," The United States Navy, http://www.chinfo.navy.mil/navpalib/factfile/ships, U.S. Navy, Washington, DC, accessed October 6, 1997.

Verdonik, D.P., DiNenno, P.J., Ball, D.N., and Shafer, R.A. (1996), "Halons as Hazardous Wastes: Policy Implications of Montreal Protocol Decision VII/12," *Proceedings of the Second Aerospace Environmental Technology Conference*, Huntsville, AL, August 6-8, 1996.

Verdonik, D.P., and DiNenno, P.J. (1996), "Halons as Hazardous Wastes: Policy Implications of Montreal Protocol Decision VII/12," *Proceedings of the International Conference on Ozone Protection Technologies,* Washington, DC, October 21-23, 1996.

Verdonik, D.P. (1997), letter to Vince Lisa, Naval Safety Center, Norfolk, VA, April 17, 1997.

Verdonik, D.P., and DiNenno, P.J. (1997), "Halons, Will They Become Hazardous Wastes?, Decision VIII/14: Availability of Halons for Critical Uses, " *Proceedings -Halon Options Technical Working Conference*, Albuquerque, NM, May 6-8, 1997.

Verdonik, D.P., Laramee, S.T., DiNenno, P.J., and Williams, F.W. (1997), "U.S. Navy Halon 1211 Replacement Plan: Part III – Halon 1211 Mission Critical Reserve Evaluation, NRL Memo Report, in preparation, 1997.

Walsh (1996-1997), series of telephone conversations with E. Walsh of NAWCADLKE, Lakehurst, NJ, November 1996 through August 1997.

Williams (1997), telephone conversations with E. Williams, Robins Air Force Base, GA, February 1997.

Wright, J.A. (1995), "Full-Scale Evaluations of Halon 1211 Replacement Agents for Airport Fire Fighting," DOT/FAA/AR-95/87, Federal Aviation Administration, FAA Technical Center, Atlantic City, NJ, October 1995.

Appendix A – Inventories

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Atlantic Division

UIC	Activity (Location)	EU (EC)	YR	Make & Model Number	LBS of 1211	Stat	Repl YR	Cost	USN	MC
N00101	NAS S. Weymouth	716001	91	AMERTEK CF4000L	0	Y	1999	$174,360	71-02860	N00072
		716001	92	AMERTEK CF4000L	0	Y	2000	$174,360	71-02914	N00072
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02682	N00072
N00109	NWS Yorktown	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02691	N00024
N00158	NAS Willow Grove	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02942	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02898	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02982	N00072
		710201	87	KOVATCH KFT6	200	O	1994	$81,864	71-02756	N00072
		716001	86	OSHKOSH P-19	500	O	1994	$174,360	71-02683	N00072
N00171	Naval District Washington	716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02800	N00011
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02801	N00011
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02803	N00011
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02703	N00011
N00178	NSWC Dahlgren	716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02947	N00024
N00204	NAS Pensacola	716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02811	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02816	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02864	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02912	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02916	N00062
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02866	N00062
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02963	N00062
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02974	N00062
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-03003	N00062
		710200	88	MAXIM X-CR	200	O	1995	$73,560	71-02791	N00062
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02694	N00062
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02704	N00062
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02726	N00062
N00206	NAS New Orleans	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02922	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02962	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02975	N00072
N00207	NAS Jacksonville	716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02847	N00060
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02945	N00060
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02951	N00060
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02953	N00060
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02977	N00060
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02979	N00060
		710200	78	CHRYSLER W400	0	P	1985	$73,560	71-02527	N00060
		710202	85	CONESTOGACK-31003	200	O	1992	$73,924	71-02670	N00060

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Atlantic Division

UIC	Activity (Location)	EU (EC)	YR	Make & Model Number	LBS of 1211	Stat	Repl YR	Cost	USN	MC
N00210	NTC Great Lakes	710202	87	KOVATCH KFT6	200	O	1994	$73,924	71-02755	N00062
N00213	NAS Key West	716001	86	OSHKOSH P-19	500	O	1994	$174,360	71-02688	N00060
		716000	87	OSHKOSH P-19	500	O	1995	$200,000	71-02735	N00060
		716001	87	OSHKOSH P-19	0	H	1995	$174,360	71-02729	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02730	N00060
N00216	NAS Corpus Christi	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02894	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02904	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02948	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02957	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02966	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02969	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02973	N00062
N00275	NAS Glenview	716000	85	OSHKOSH P-19	500	O	1993	$200,000	71-02709	N00025
N00389	NS Rosy Roads	710200	87	KOVATCH KFT6	200	O	1994	$73,560	71-02770	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02740	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02929	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02932	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02938	N00060
N00421	NAWC Paxtuxent River	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02697	N00019
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02701	N00019
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02728	N00019
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02936	N00019
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02995	N00019
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02996	N00019
N00639	NSA Memphis Millington	710200	87	KOVATCH KFT6	200	O	1994	$73,560	71-02772	N00062
		716000	85	OSHKOSH P-19	0	Y	1993	$200,000	71-02689	N00062
		716001	87	OSHKOSH P-19	0	Y	1995	$174,360	71-02736	N00062
		716001	87	OSHKOSH P-19	0	Y	1995	$174,360	71-02737	N00062
N60087	NAS Brunswick	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02907	N00060
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02970	N00060
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02861	N00060
N60191	NAS Oceana	716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02804	N00060
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02809	N00060
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02817	N00060
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02896	N00060
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02911	N00060
		716001	93	AMERTEK CF4000L	500	O	2001	$174,360	71-02958	N00060
		716001	93	AMERTEK CF4000L	500	O	2001	$710,959	71-02959	N00060

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Atlantic Division

UIC	Activity (Location)	EU (EC)	YR	Make & Model Number	LBS of 1211	Stat	Repl YR	Cost	USN	MC
N60200	NAS Cecil Field	716001	90	AMERTEK CF4000L	0	Y	1998	$174,360	71-02805	N00060
		716001	90	AMERTEK CF4000L	0	Y	1998	$174,360	71-02818	N00060
		716001	90	AMERTEK CF4000L	0	Y	1998	$174,360	71-02902	N00060
		716001	90	AMERTEK CF4000L	0	Y	1998	$174,360	71-02917	N00060
		716001	91	AMERTEK CF4000L	0	Y	1999	$174,360	71-02812	N00060
		716001	93	AMERTEK CF4000L	0	Y	2001	$174,360	71-02926	N00060
		716001	93	AMERTEK CF4000L	0	Y	2001	$174,360	71-02954	N00060
		710200	77	CHRYSLER W-40	200	O	1984	$73,560	71-02503	N00060
N60201	NS Mayport	716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02741	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02742	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02751	N00060
N60241	NAS Kingsville	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02949	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02967	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02862	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02903	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02909	N00062
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02960	N00062
N60508	NAS Whiting Field, Milton	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02908	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02952	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02972	N00062
		716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02976	N00062
		710202	83	FIRE-TEC CK30943	200	O	1990	$73,924	71-02637	N00062
		710202	83	FIRE-TEC CK30943	200	O	1990	$73,924	71-02638	N00062
		710202	83	FIRE-TEC CK30943	200	O	1990	$73,924	71-02639	N00062
		710202	83	FIRE-TEC CK30943	200	O	1990	$73,924	71-02641	N00062
		710202	83	FIRE-TEC CK30943	200	O	1990	$73,924	71-02642	N00062
		710202	85	GMC CHEV CK31003	200	O	1992	$73,924	71-02677	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02775	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02776	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02777	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02778	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02779	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02780	N00062
		710200	87	GMC CHEV KFT6	200	O	1994	$73,560	71-02781	N00062
		710202	88	GMC CHEV X-CR	200	O	1995	$73,924	71-02787	N00062
		710202	88	GMC CHEV X-CR	200	O	1995	$73,924	71-02788	N00062
		710202	88	GMC CHEV X-CR	200	O	1995	$73,924	71-02789	N00062
		710202	88	GMC CHEV X-CR	200	O	1995	$73,924	71-02790	N00062

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Atlantic Division

UIC	Activity (Location)	EU (EC)	YR	Make & Model Number	LBS of 1211	Stat	Repl YR	Cost	USN	MC
N61331	NSWC Panama City	716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02743	N00024
N61414	NAB Little Creek	710200	86	KOVATCH KFT4	200	O	1993	$73,560	71-02720	N00060
N62588	NSA Naples	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02695	N00061
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02696	N00061
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02747	N00061
N62661	NETC Newport	710202	85	GMC CHEV CK30	200	O	1992	$73,924	71-02679	N00062
N62688	NS Norfolk	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02687	N00060
		716001	86	OSHKOSH P-19	500	O	1994	$174,360	71-02692	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02748	N00060
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02749	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02930	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02937	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02990	N00060
N62863	NS Rota	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02684	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02933	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02940	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02991	N00061
N62995	NAS Sigonella	716000	85	OSHKOSH P-19	500	O	1993	$200,000	71-02686	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02934	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02941	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02989	N00061
N63032	NAS Keflavik	710200	83	FIRE-TEC DC15	200	O	1990	$73,560	71-03014	N00060
		710200	95	FORD MTR F-400	0	E	2002	$73,560	71-03024	N00060
		710200	87	GMC TRK CK1003	200	O	1994	$73,560	71-02760	N00060
		710200	83	NAVISTAR 1854	200	O	1990	$73,560	71-02985	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02928	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02935	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02988	N00060
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-02994	N00060
N63043	NAS Meridian	716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02802	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02848	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02855	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02856	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02900	N00062
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02918	N00062
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02943	N00062
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02965	N00062

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Atlantic Division

UIC	Activity (Location)	EU (EC)	YR	Make & Model Number	LBS of 1211	Stat	Repl YR	Cost	USN	MC
N63821	NUWC Andros Island	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02702	N00024
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02734	N00024
N66691	NSA Souda Bay	710200	84	CHEV AS32	200	O	1991	$73,560	71-03084	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-03000	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-03001	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-03002	N00061
		719001	92	OSHKOSH TA3000	500	O	2004	$329,496	71-03027	N00061
N68335	NAWC Lakehurst	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02712	N00019
		716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02714	N00019
		716001	86	OSHKOSH P-19	500	O	1994	$174,360	71-02722	N00019
		716001	87	OSHKOSH P-19	500	O	1995	$174,360	71-02782	N00019
N83447	NAS Fort Worth	716001	90	AMERTEK CF4000L	500	O	1998	$174,360	71-02961	N00072
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02808	N00072
		716001	91	AMERTEK CF4000L	500	O	1999	$174,360	71-02815	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02906	N00072
		716001	92	AMERTEK CF4000L	500	O	2000	$174,360	71-02950	N00072
N92782	NWIRP Bloomfield	716001	85	OSHKOSH P-19	500	O	1993	$174,360	71-02690	N00019
N68860	NSC Pensacola	710200	82	CHEV CK31403	200	O	1989	$73,560	73-03052	N00023
		710200	79	FORD MOTRF600	200	O	1986	$73,560	73-02670	N00023
		716000	86	OSHKOSH P-19	500	O	1994	$200,000	71-02796	N00023

TOTAL LBS HALON 1211- ATL	68400
TOTAL LBS HALON 1211- PAC	*33500*
TOTAL LBS HALON 1211	**101900**

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Pacific Division

UIC	Activity (Location)	EU (EC)	Yr.	Make & Model No.	Lbs. of 1211	Stat.	Repl. Yr.	Cost	USN	MC
N00236	NAS Alameda	716001	91	AMERTEK CF4000L	500				71-02807	N00070
		716001	92	AMERTEK CF4000L	500				71-02919	N00070
		716001	92	AMERTEK CF4000L	500				71-02921	N00070
		710200	83	CHRYSLER D350	200				71-03005	N00070
		710200	87	KOVATCH KFT06	200				71-02759	N00070
N00242	Naval Base San Diego	716000	90	AMERTEK CF4000L	500				71-02814	N00070
		716000	90	AMERTEK CF4000L	500				71-02865	N00070
		716000	90	AMERTEK CF4000L	500				71-02910	N00070
		716001	90	AMERTEK CF4000L	500				71-02867	N00070
		716001	90	AMERTEK CF4000L	500				71-02971	N00070
		716001	90	AMERTEK CF4000L	500				71-02978	N00070
		710202	85	CONESTOGACK-31003	200				71-02680	N00070
		710200	86	KOVATCH KFT-4	200				71-02717	N00070
		719001	92	OSHKOSH IA-3000	500				71-02939	N00070
		716001	85	OSHKOSH P-19	500				71-02693	N00070
		716001	85	OSHKOSH P-19	500				71-02705	N00070
		716001	85	OSHKOSH P-19	500				71-02708	N00070
		716001	87	OSHKOSH P-19	500				71-02732	N00070
		716001	85	OSHKOSH P19	500				71-02706	N00070
		719001	92	OSHKOSH TA-3000	500				71-02987	N00070
N00620	NAS Whidbey Island	716000	90	AMERTEK CF4000L	500				71-02863	N00070
		716001	90	AMERTEK CF4000L	500				71-02955	N00070
		716001	92	AMERTEK CF4000L	500				71-02905	N00070
		716001	92	AMERTEK CF400L	500				71-02901	N00070
		710200	84	CHRYSLER D-350	200				71-03007	N00070
		710201	77	CHRYSLER W400	0	H			71-02502	N00070
		710202	86	KOVATCH KFT-4	200				71-02718	N00070
		716001	87	OSHKOSH P-19	500				71-02731	N00070
N0534A	Pacific Missile Range Facility	716001	92	AMERTEK CF4000L	500				71-02913	N00070
		710201	79	CHRYSLER W400	200				71-02580	N00070
		716001	85	OSHKOSH P-19	500				71-02710	N00070
		716001	87	OSHKOSH P-19	500				71-02738	N00070
N60028		710200	84	CHRYSLER D-350	200				71-03011	N00070

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Pacific Division

UIC	Activity (Location)	EU (EC)	Yr.	Make & Model No.	Lbs. of 1211	Stat.	Repl. Yr.	Cost	USN	MC
N60042	NAF El Centro	716001	90	AMERTEK CF-4000	500				71-02946	N00070
		716000	91	AMERTEK CF-4000	500				71-02899	N00070
		716001	91	AMERTEK CF-4000	500				71-02924	N00070
		716000	91	AMERTEK CF 4000L	500				71-02806	N00070
		710200	87	KOVATCH KFT06	200				71-02764	N00070
N60462	NAF ADAK	716000	90	AMERTEK CF 4000L	500				71-02858	N00070
		716000	90	AMERTEK CF4000L	500				71-02859	N00070
		716000	91	AMERTEK CF4000L	500				71-02857	N00070
N60495	NAS Fallon	716001	92	AMERTEK CF4000L	500				71-02895	N00070
		716001	92	AMERTEK CF4000L	500				71-02923	N00070
		716001	93	AMERTEK CF4000L	500				71-02980	N00070
		710200	84	CHRYSLER D-350	200				71-03008	N00070
		710201	78	FIRE-TEC W400	200				71-02497	N00070
		719001	93	OSHKOSH TA-3000	500				71-03028	N00070
N60530	NAWC China Lake	716001	92	AMERTEK CF4000L	500				71-02956	N00019
		716001	93	AMERTEK CF400L	500				71-03004	N00019
		710200	77	CHRYSLER W-400	200				71-02514	N00019
		716001	85	OSHKOSH P19	500				71-02711	N00019
N62494	US NAF	710202	86	KOVATCH KFT4	200				71-02719	N00025
		716001	87	OSHKOSH P19	500				71-02745	N00025
		716001	87	OSHKOSH P19	500				71-02746	N00025
N62813	NS Pearl Harbor, HI	716000	92	AMERTEK CF4000L	500				71-02845	N00070
		716001	92	AMERTEK CF4000L	500				71-02819	N00070
		716001	92	AMERTEK CF4000L	500				71-02846	N00070
		716001	93	AMERTEK CF4000L	500				71-02968	N00070
		710202	85	CONESTOGA45152	200				71-02667	N00070
		710202	85	CONESTOGA45152	200				71-02715	N00070
		716001	85	OSHKOSH P-19	500				71-02698	N00070
		716001	85	OSHKOSH P-19	500				71-02699	N00070
N63042	NAS LeMoore	716001	90	AMERTEK CF4000L	500				71-02897	N00070
		716001	91	AMERTEK CF4000L	500				71-02813	N00070
		716001	92	AMERTEK CF4000L	500				71-02920	N00070
		716001	92	AMERTEK CF4000L	500				71-02944	N00070
		710200	84	CHRYSLER D-350	200				71-03009	N00070
		710200	87	KOVATCH KFT06	200				71-02773	N00070

Crash Fire and Rescue (CFR) Equipment
Halon 1211 Containing Equipment
Pacific Division

UIC	Activity (Location)	EU (EC)	Yr.	Make & Model No.	Lbs. of 1211	Stat.	Repl. Yr.	Cost	USN	MC
	Pacific Missile Test Center									
N63126	Pt. Mugu	716000	90	AMERTEK CF4000L	500				71-02810	N00019
		716000	92	AMERTEK CF4000L	500				71-02964	N00019
		710200	95	FORD MTR F800	200				71-03060	N00019
		710200	95	FORD MTR F800	200				71-03061	N00019
		716001	85	OSHKOSH P19	500				71-02713	N00019
		716001	87	OSHKOSH P19	500				71-02752	N00019
		716001	87	OSHKOSH P19	500				71-02753	N00019
N68539	Diego Garcia	710200	87	KOVATCH KFT-6	200				71-02774	N00070
		716001	87	OSHKOSH P19	500				71-02750	N00070
		719001	92	OSHKOSH TA-3000	500				71-02992	N00070
		719001	92	OSHKOSH TA3000	500				71-02927	N00070
		719001	92	OSHKOSH TA3000	500				71-02999	N00070
		TOTAL LBS HALON 1211- PAC			33500					
		TOTAL LBS HALON 1211- ATL			*68400*					
		TOTAL LBS HALON 1211			101900					

			RQRD P-16	RQRD TAU-2(H	RQRD 1500 LBs	POUNDS 1211
CV 62	USS INDEPENDENCE	YOKOSUKA, JA	3	3	3	6750
CV 63	USS KITTY HAWK	SAN DIEGO, CA	3	3	3	6750
CV 64	USS CONSTELLATION	SAN DIEGO, CA	3	3	3	6750
CV 67	USS JOHN F KENNEDY	MAYPORT, FL	3	3	3	6750
CVN 65	USS ENTERPRISE	NORFOLK, VA	3	3	3	6750
CVN 68	USS NIMITZ	BREMERTON, WA	3	3	3	6750
CVN 69	USS DWIGHT D EISENHOWER	NORFOLK, VA	3	3	3	6750
CVN 70	USS CARL VINSON	BREMERTON, WA	3	3	3	6750
CVN 71	USS THEODORE ROOSEVELT	NORFOLK, VA	3	3	3	6750
CVN 72	USS ABRAHAM LINCOLN	BREMERTON, WA	3	3	3	6750
CVN 73	USS GEORGE WASHINGTON	NORFOLK, VA	3	3	3	6750
CVN 74	USS JOHN C. STENNIS	NORFOLK, VA	3	3	3	6750
CVN 75	*HARRRY S TRUMAN*	*NEW*	3	3	3	*6750*
CVN 76	*RONALD REAGAN*	*NEW*	3	3	3	*6750*
LPH 9	USS GUAM	NORFOLK, VA	2	2	2	4500
LPH 11	USS NEW ORLEANS	SAN DIEGO, CA	2	2	2	4500
LHA 1	USS TARAWA	SAN DIEGO, CA	2	2	2	4500
LHA 2	USS SAIPAN	NORFOLK, VA	2	2	2	4500
LHA 3	USS BELLEAU WOOD	SASEBO, JA	2	2	2	4500
LHA 4	USS NASSAU	NORFOLK, VA	2	2	2	4500
LHA 5	USS PELELIU	SAN DIEGO, CA	2	2	2	4500
LHD 1	USS WASP	NORFOLK, VA	2	2	2	4500
LHD 2	USS ESSEX	SAN DIEGO, CA	2	2	2	4500
LHD 3	USS KEARSARGE	NORFOLK, VA	2	2	2	4500
LHD 4	USS BOXER	SAN DIEGO, CA	2	2	2	4500
LHD 5	USS BATAAN	NEW	2	2	2	4500
LHD 6	*USS BON HOMME RICHARD*	*NEW*	2	2	2	*4500*
TRAINING	NAWC LAKEHURST		1	1	NA	*750*
	NAS NORTH ISLAND		1	1	NA	*750*
	NAS JACKSONVILLE		1	1	NA	*750*
	NATTC PENSACOLA		2	0	NA	*800*
	LOGISTICS SYSTEM		4	0	NA	*1600*
TOTAL	**CURRENT FIELDING**		**69**	**63**	**60**	**139650**
LPD 4	*USS AUSTIN*	*NORFOLK, VA*		2	1	*2200*
LPD 5	*USS OGDEN*	*SAN DIEGO, CA*		2	1	*2200*
LPD 6	*USS DULUTH*	*SAN DIEGO, CA*		2	1	*2200*
LPD 7	*USS CLEVELAND*	*SAN DIEGO, CA*		2	1	*2200*
LPD 8	*USS DUBUQUE*	*SASEBO, JA*		2	1	*2200*
LPD 9	*USS DENVER*	*SAN DIEGO, CA*		2	1	*2200*
LPD 10	*USS JUNEAU*	*SAN DIEGO, CA*		2	1	*2200*
LPD 12	*USS SHREVEPORT*	*NORFOLK, VA*		2	1	*2200*
LPD 13	*USS NASHVILLE*	*NORFOLK, VA*		2	1	*2200*
LPD 14	*USS TRENTON*	*NORFOLK, VA*		2	1	*2200*
LPD 15	*USS PONCE*	*NORFOLK, VA*		2	1	*2200*
LPD 17	*SAN ANTONIO*	*NEW*		2	1	*2200*
LPD 18	*CONTRACT OPTION*			2	1	*2200*
LPD 19	*CONTRACT OPTION*			2	1	*2200*
TOTAL	***FUTURE REQUIREMENTS***		***77***	***99***	***82***	***188450***

The following is provided for your information regarding the number of P-19's available within the Marine Corps.

Grand Total:	185
Assigned to Air Stations/Facilities	-71
Balance:	114
Assigned to Marine Wing Support Squadrons:	-40
Balance:	74
Assigned to Maritime Prepositioning Forces:	24
Balance:	50
Assigned to Reserve Marine Units:	16
Balance:	34
Assigned to Goodfellow Air Force Base:	4
Balance:	30
Assigned to Force Service Support Groups:	4
Balance:	26
Assigned to Albany/War Reserves:	26
Balance:	0

All vehicles fielded in Calendar Years 1984-1985-1986
Initial Service Life of Vehicle: 10 Years (1994-1995-1996)
A truck that is overhauled (i.e. #18) will receive an extended service life of 10 years.

Appendix B – Sample Incident Report

Legend

A = ARMY
F = AIR FORCE
N = NAVY
M = MARINES
L = DLA

TYPE SITUATION FOUND

440	AIRCRAFT FUEL TANK FIRE (WING, CENTERLINE, INTERNAL, EXTERNAL OR FUEL VENTS)
441	AIRCRAFT ENGINE FIRE
442	AIRCRAFT ELECTRICAL FIRE
443	AIRCRAFT WHEEL OR BRAKE FIRE
444	AIRCRAFT STARTER CARTRIDGE FIRE
445	AIRCRAFT FIRE, NUCLEAR/CONVENTIONAL WEAPONS ON BOARD AND INVOLVED IN FIRE
446	AIRCRAFT FIRE, NUCLEAR/CONVENTIONAL WEAPONS ON BOARD AND NOT INVOVED IN FIRE
449	NOT CLASSIFIED
451	AIRCRAFT CRASH WITH FIRE
452	AIRCRAFT CRASH WITH NO FIRE
453	AIRCRAFT CRASH NUCLEAR/CONVENTIONAL WEAPONS ON BOARD AND INVOLVED IN FIRE
459	NOT CLASSIFIED

===

METHOD OF EXTINGUISHMENT

1	SELF EXTINGUISHED
2	MAKE SHIFT AIDS (INCLUDED ARE GARDEN HOSE, SAND, RAKES, SHOVELS, BAKING SODA, AND ALIKE
3	PORTABLE EXTINGUISHERS
4	AUTOMATIC EXTINGUISHING SYSTEM
5	PRECONNECTED HOSELINE(S) WITH WATER CARRIED IN APPARATUS TANKS
8	MASTER STREAM DEVICE(S) WITH OR WITHOUT HAND LINE(S)
9	NOT CLASSIFIED

===

EXTINGUISHMENT AGENT

07 = HALOGENATED AGENT HALON 1211

===

EXTINGUISHMENT QUANTITY

VALUE EQUALS EXACT AMOUNT USED

===

EXTINGUISHMENT UNIT OF MEASURE (UOM)

2 = POUNDS

===

Sample Incident Report

svc	N
arvl_date	
arvl_time	1938
event_date	08/30/1995
time_unit_cleard	
type_sitn_found_c	441
fy	1995
extgshm_agent_c	07
extgshm_qty	5
extgshm_uom_c	2
mthd_of_extgshm_c	3
rprtbl_event_narr	

AT 1937 HRS CONTROL TOWER CALLED ON CRASH NET RADIO THAT F14 ON KING SPOT CALLED FOR ASSISTANCE FROM CRASH CREW. ASST. FIRE CHIEF, R
ESCUE VEHICLE, AND 2 CFR UNITS RESPONDED. AIRCRAFT HAD EXPERIENCED A WET START ON STARBOARD ENGINE. MAINTENANCE PERSONNEL USED HALON
EXTINGUISHER TO EXTINGUISH FIRE. AIRCRAFT WAS CHECKED BY FIRE DEPARTMENT AND THEN RELEASED TO MAINTENANCE PERSONNEL.